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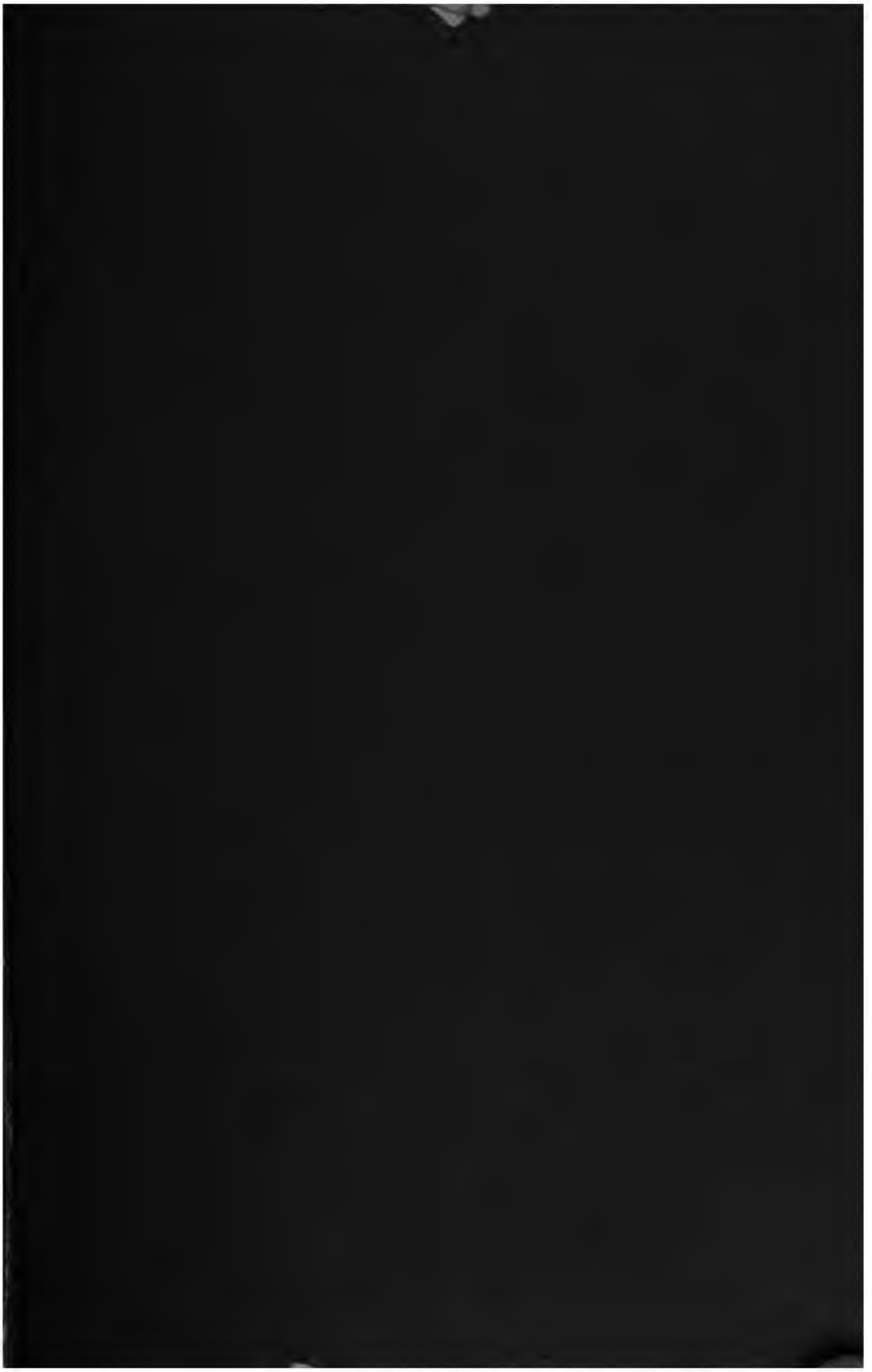

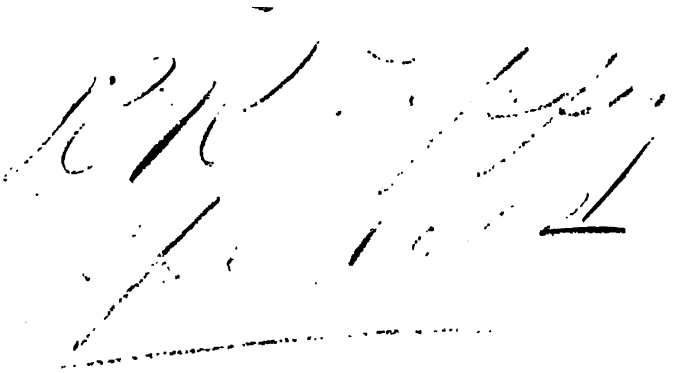

R R TOPPING

A PRACTICAL TREATISE

ON THE MANUFACTURE OF

STARCH, GLUCOSE, STARCH-SUGAR, AND DEXTRINE.

A PRACTICAL TREATISE

ON THE MANUFACTURE OF

STARCH, GLUCOSE, STARCH-SUGAR, AND DEXTRINE.

BASED ON THE GERMAN OF

LADISLAUS VON WAGNER,
PROFESSOR IN THE ROYAL TECHNICAL HIGH SCHOOL, BUDA-PEST, HUNGARY,

AND OTHER AUTHORITIES,

BY JULIUS FRANKEL,
GRADUATE OF THE POLYTECHNIC SCHOOL OF HANOVER.

EDITED BY ROBERT HUTTER,
CHEMIST, PRACTICAL MANUFACTURER OF STARCH-SUGAR; PROPRIETOR OF THE PHILADELPHIA STARCH-SUGAR WORKS.

Illustrated by 58 engravings, covering every branch of the subject; including examples of the most recent and best American machinery.

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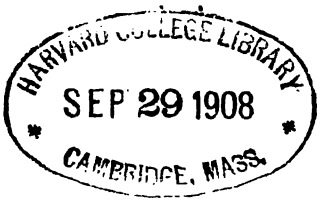

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R R TOPPING

PREFACE.

THE sudden and unexpected death of JULIUS FRANKEL, while this volume was passing through the press, renders it proper that some notice should be made of him in this place. Mr. Frankel was born at Hildesheim, Hanover, Germany, August 26, 1831; was educated under the eminent Dr. Karl Karmarsch, at the Polytechnic School in the city of Hanover; came to the United States in 1850, and died in Philadelphia, April 28, 1881. He was a learned, an industrious, and an amiable man, thoroughly versed in several languages, and a good technical scholar, who was well acquainted with the literature of this special branch of knowledge. It need hardly be said that such a man was of incalculable value to an industrial publishing house. He had done other and good work for us, was thoroughly appreciated by us, as well personally as professionally, and we had looked forward with satisfaction to his future usefulness to us. Our relations were so far agreeable to him that they seemed to infuse into him new life, energy, and hope, when, unhappily, he was suddenly stricken by the disease which in a few days brought to an end his useful career. To us his loss is very great; to his family it is indeed overwhelming and irreparable. It affords us a melancholy satisfaction to pay this slight tribute to his worth.

The volume now presented to American readers, is upon a class of industries which has been surrounded by more mystery than probably any others of recent years. This has been so studied and persistent that not only has access to factories been barred to all but workmen, but even the inventors and manufacturers of the necessary machinery have refused to furnish drawings of the machines. This work, which is the

only one on the subject ever published in the English language, is mainly based upon that of Professor Ladislaus von Wagner, of Buda-Pest, Hungary, the very best book which has appeared in Europe, and which was really undertaken with a view to advance and improve a group of industries, which had suffered from mystery, secret processes, and empiricism, and the lack of progress, which are inseparable from such modes of procedure in any industry. Among those who with particular liberality assisted Prof. Wagner may be named Mr. Fr. Anthon, of Prague, Bohemia, the manufacturer of the purest and finest starch-sugar which is made in the world.

The present treatise was prepared with great care, intelligence, and zeal by the late Mr. Frankel, and it has been critically and conscientiously edited by Mr. Robert Hutter, of this city, who is eminently qualified for the work as well by his education as by his present profession of manufacturer of starch-sugar. It is now submitted to the American public with entire confidence in its being a thoroughly practical and valuable addition to industrial literature.

H. C. B.

PHILADELPHIA, May 21, 1881.

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A PRACTICAL TREATISE

ON THE

MANUFACTURE OF STARCH, GLUCOSE, STARCH-SUGAR, AND DEXTRINE.

SECTION I.

THE CHEMISTRY OF STARCH.

INTRODUCTORY.

STARCH, or starch-flour, was known to the ancient Egyptians and Greeks, but at that remote age it was exclusively manufactured of wheat. The starch produced by the inhabitants of the island of Chios was much valued, and was used for medicinal purposes as well as for food. According to Pliny, we are indebted for the making of starch from wheat to the inhabitants of Chios. But the production and application of starch from potatoes appears to be an invention of more recent times, and dates from the close of the 16th and the beginning of the 17th century, while the literature pertaining to this branch of industry commences with the year 1739; since which time many treatises on this subject have made their appearance in the various languages of continental Europe.

APPEARANCE AND VALUE.

Starch is not only one of the most extensively diffused, but also one of the most useful ingredients con-

tained in plants. It is important on account of its scientific relations, with regard to the vitality of plants and their chemical action, and of the highest practical interest in the industrial arts, and for domestic and agricultural purposes. Starch appears not only in all the different species of plants, but it is found in all the various parts of the same. Starch appears in the roots, bulbs, and stalks, in the trunks (both in the wood and in the bark of trees), as also in the leaves, blossoms, fruits, and seeds of the most varied species of plants. Many plants and products prepared from plants, which serve as nutriment for man and beast, are distinguished on account of their large yield of starch, as, for instance, the various species of grain, such as corn, wheat, rice, rye, barley, maize, etc.

In order to be enabled to separate the starch from the plants to make it remunerative, it becomes above all necessary to be able to gather the respective vegetable substances in large quantities, and such of a rich yield, that the separation of the starch ensues without difficulty, and finally, that the product obtained possesses withal those properties whereby it becomes valuable for the different purposes. It occurs, however, frequently that starch might be separated inexpensively and in large quantities, but that such starch contains such properties as make it quite useless for any practical purposes. Such starch is frequently of various colors, or it has an admixture of foreign ingredients, to remove which would entail expense, not worth the trouble, and hence for practical purposes it would be entirely or partly useless.

Among the products from the vegetable world, which yield *commercial starch*, we name the following,

viz., potatoes, wheat, maize, and rice, and to the elucidation of these products this treatise will be more prominently devoted.

The value or percentage of starch contained in these various species of corn and grain—dried in an atmosphere of 100° C. (212° F.)—can be gleaned from the following table:—

	According to Krocker's analysis.		Mean ratio.
	From	To	
Wheat	66.98	67.42	67.20
Rye	60.56	61.26	60.90
Maize	77.74	.....	77.77
Rice	85.78	86.63	82.30
Potatoes	70.50	83.50	76.50
Potatoes (air-dry)	12.70	20.71	16.50

As the percentage of the product of starch mentioned above is given as it appears in the air-dry state, it will be necessary also to include here the quantity of *hygroscopic* water contained in the different species, for which purpose the table below may serve.

	Starch.	Protein substances.	Fat.	Ashy ingredients.	Fibrin.	Water.
Wheat	63.8	14.4	1.9	1.7	4.2	14.5
Rice	74.5	7.8	0.2	0.3	3.4	13.7
Maize	64.5	9.9	6.7	1.4	4.0	13.5
Potatoes	20.0	....	....	....	....	76.0

Formation, Substance, and Nature of Starch.

Starch, according to the opinion of the scientific men of the present age—even without regard to its organized structure—is merely to be considered as a product formed by the vital activity of plants, and hitherto

chemistry has not been able to produce a body which would even possess the chemical properties of the same, while we are enabled by chemical process to produce substances which approach it—for instance, gum (dextrine), starch-sugar, glucose, etc. The formation of starch in animalic substances, hitherto problematical, we will not consider here, although some have endeavored to prove its existence in the spleen, the liver, and the kidneys of animals.

The formation of starch pertains, beyond doubt, to one of the most vital actions in the life of plants, and it is most probable that it originates from the gum-resin or mucilaginous matter. In many instances, starch is to be considered as the final product in the process of vegetable life, while in other respects it appears manifestly as a product of transition. In the latter case it disappears again at a certain period, in order to serve as material for other substances (gum, sugar, etc.), or, and principally perhaps, to be used for the structure of the cellular tissue in the form of vegetable fibre (cellulose). Thus for instance unripe kernel fruit contains large quantities of starch, which however disappears when the fruit ripens. It is a fact, based on science, that starch and fibres come near in their chemical properties, and this will become all the more obvious when it is considered that they really possess the same chemical constitution, since the *cellulose* may be considered as being starch in a more cohesive state.

The disappearance of the starch already formed does not take place at the time of the actual germination of the seeds in the ground, or at the period of the malting of the grain, nor does it happen at the

time of the sprouting of the potatoes at their place of keeping, etc., but it ensues (especially in the case of potatoes) in consequence of their containing a large quantity of water at the beginning of germination, and this circumstance furnishes the reason for the fact that the amount of starch in potatoes which increases with their maturing and ripening, gradually decreases during their being kept in store, or during winter.

It has been asserted that the want of light tends to increase the formation of starch, but this opinion we deem fallacious, since those parts of plants which are more particularly excluded from the influences of light, do not contain a larger amount of starch, but as is well known, the yield in starch of the various species of grain is much larger than that of the potato, and it can certainly not be asserted of either grain or maize, that their richer yield in starch is to be derived from the consequence of want of light during their process of development.

The main point in question is to ascertain the manner of the formation and growth of the starch granules. For the correct solution of this difficult question we are indebted to the investigations of *Nœgeli*, who has furnished the proof that the growth of the starch granules ensues by the penetration of starch producing liquid hydrates of carbon. They penetrate from without into the interior of the grain. The substance of the starch granules increases in density from within to without, while the quantity of moisture increases from without to within. The starch granules consist of an outer denser layer having but little moisture, followed by one of lesser density, but containing more water, upon this follows again a denser

layer of smaller amount of water, etc. etc., until finally in the centre a soft, more water-containing nucleus is found. The botanist *Schleiden* was the first who observed that the inner strata of starch granules generally abound more in water, and are consequently more gelatinous, the outer layers less moist and are therefore denser.

Starch consists of an easily soluble mass, the "granulose," and an insoluble substance, "starch cellulose." Both these substances are distributed through the entire body of the starch granules, and not merely separated and deposited in the various layers of the grain. *Fibrin* (cellulose), according to its chemical nature, is an ingredient which is always homogeneous, and a prominent part in all plants; forming in the shape of cellular tissues, so to say, the skeleton of the plants. Fibrin, as already stated, has much that is similar to starch, and both form, when exposed to the action of sulphuric acid, dextrine and sugar; both are transformed by the application of caustic alkalies and nitric acid into oxalic acid; both form under certain conditions explosives, the starch *xylodin*, the plant fibre gun-cotton (*pyroxilin*).

Starch is frequently considered as that substance (nutriment), by which the cellular tissues of plants are formed; and many physiologists assert that the fibre itself can be retransformed even in the plant into starch, which latter opinion is nevertheless dubious.

Berzelius distinguished two different forms of fibrin in plants: first, that which is found in wood and hard shells and seeds (for instance in the coffee bean); and secondly as cellular skeleton of the softer parts of plants, for instance that in beets, and various other truck vegetables; the former he termed *Xylon* or

strong cellulose, the latter *Amylon*, that is tender (soft) cellulose.

Physical Properties.

Organization, Structure, Form and Size.—The starch appears as deposited in the tissues of plants, when being viewed under the lens of a microscope, like rounded-off, colorless, transparent, or glassy lustrous globules of various sizes, form (shape), and aggregation, partly more or less spherical, and again more of an eliptical shape (lentil formed), *i. e.*, pressed flat, disk-like, and occurring either in single (simple) granules or bar-shaped, adhering or stuck together.

Dry starch, especially potato starch, appears as a white, glossy, in the sunlight glittering, powder, somewhat hard of touch and of 1.53 specific gravity (1.505 at 19.7° C. = 67.5° F.). Moistened starch can be formed into balls, which even after drying adhere together, and do not break up, without the use of some force. After a complete extraction by cold water, alcohol or ether, it loses those properties, by which it may be turned into balls, and therefore the properties cannot be ascribed to the starch itself, but to the extractive nature of the ingredients of its composition. Chemically pure starch forms a tasteless, odorless powder, entirely indissoluble in water, alcohol, and ether. The polarization of starch is of great interest, but the various kinds do not polarize uniformly.

Among other physical properties of starch, it should be finally mentioned that, when it is brought in contact with aqueous vegetable decoctions, also with wine, beer, etc., it will discolor the same, that is, it will extract the pigment therefrom. The size of the starch

granules varies considerably, not only among the various kinds, but also among the same kind, according to the age and the advancement in the growth of the granules, as well as with regard to the organization of the plant from which they originated.

Chemical Properties.

The More Immediate Ingredients of Starch.—Starch, with regard to its chemical nature, belongs to chemically indifferent substances, *i. e.*, to the so-called hydrates of carbon, or to that group of organic bodies which, besides carbon, contain hydrogen and oxygen in such proportions that they could form water when combined with each other. The general formula for hydrates of carbon is, $C_xH_nO_n$, or $C_x(H_2O_n)$, or $C_x(H_2O)_n$.

In the group of hydrates of carbon we count, among others, cellulose, starch, dextrine, cane-sugar, milk-sugar, grape-sugar, etc. As regards its elementary composition, starch in a perfectly pure and dry state is composed of—

12 equivalents of carbon,
10 " hydrogen, and
10 " oxygen,

hence the formula = $C_{12}H_{10}O_{10}$, or, according to modern style, $C_6H_{10}O_5$, and corresponds, therefore, as to its composition, with that of fibrin (cellulose) and dextrine entirely.

In a perfectly air-dry state, starch contains 18 per cent., or four equivalents of water, of which, however, two equivalents or one-half will evaporate in a vacuum over concentrated sulphuric acid. As has

already been stated, the various layers, of which every single starch granule is formed, do not differ chemically, except as to the somewhat larger amount of water contained in those of the inner strata.

Although starch contained in different plants is, as to its chemical relations, entirely identical, yet, considered from an industrial or mercantile point of view, it essentially differs. In its perfectly pure state, it is designated generally as odorless and tasteless; however, potato starch has always a peculiar smell, which, according to *Payen*, originates from small portions of volatile oil.

Starch never appears in an entirely pure state. It always contains—although mostly in but very minute portions—some natural impurities, such as chlorophyll, solid and volatile oils, and wax, besides the incidental impurities while being manufactured, such as fibrous matter, earths and salts, imparted as impurities by water used for the washing of the same, albumen, alum, etc., which latter, as to its ratio of percentage contained in commercial starch, sometimes amounts to a great deal.

The Relations of Starch to Warmth, Water, Acids, Bases, Alkalies, and Diastase.—It has been known for a long time that starch when roasted—like gum—becomes soluble in water, but the products ensuing by this transformation were not known. Only at a later period was it proved that starch, by the process of roasting, is transformed into dextrine, or starch-gum, which process can be greatly accelerated by the addition of small quantities of acids, especially muriatic, nitric, or sulphuric acid, whereby also various quantities of starch- or grape-sugar (glucose) are formed.

It is self-evident that higher or lower temperatures acting on the starch will bring divers products. Thus perfectly dry starch can bear a temperature of 160° C. (320° F.) without a material change, but when this heat is increased to 200° C. (392° F.) the starch will turn into brownish-yellow, and thereby change into dextrine. Moist starch-flour (containing about 10 to 20 per cent. of water) will, in a closed vessel, under the simultaneous influence of steam and increased pressure, change readily at a temperature of 160° C. (320° F.) into dextrine.

The action of starch at the freezing point is highly interesting. *Vogel* observed that starch, when boiled in water, and the paste thus obtained exposed to freezing, will, when thawing, not retain its former uniform condition. But a translucent aqueous liquid will then separate, while on the bottom of the vessel an elastic substance will remain, which is no longer suitable for pasting. This mass furnishes, when strained off through linen, a corresponding quantity of clear water (in which but very little starchy substance appears dissolved), and also a nice white cake, which latter, after a short time, becomes so dry that it can be grated into a fine white powder, which, when treated in hot water, again swells up, but without forming the same cohesive pasty mass as before.

Starch treated in this manner may be applied in the process of manufacturing the finest qualities of paper, particularly of entirely translucent parchment paper, also for preparing perfectly pure colodion, as well as for other purposes of the arts. The so-called *pearly lustre* for the use of bookbinders, is prepared in this manner.

Relations of Starch to Water.—To cold water starch is entirely indifferent, and settles in it when by diligent stirring it has become divided into small parts, and after the liquid is thus allowed again to settle on the bottom it will show no perceptible change either in the quantity or the quality. If starch is heated in from twelve to fifteen times its quantity of water to 58° C. (136.4° F.), the starch granules begin to swell, and the higher the temperature is increased, the larger the quantity of the granules will be, which show the same symptoms. Gradually more starch granules will expand, and this will ensue in the case of some kinds of starch already at 55° to 87.5° C. (131° to 189.5° F.). They will, moreover, expand in such a manner that the single layers will burst open, and by a copious absorption of water by the spongy mass, the so-called paste formation will ensue. Paste, which has been formed in a temperature below 100° C. (212° F.) contains no starch in solution, but is merely to be regarded as a product of the swelling of its separate granules, which in this burst or cracked condition—as it were a sponge—are able to absorb an extraordinary amount of water. The absorbed water can, however, be again drained off, by repeatedly placing it on porous filters (slabs of clay, tissue paper, etc.), when after drying a horny substance will remain, which after pulverizing is again ready to form a paste.

The ability to form paste, or the stiffening power inherent in the various starches, differs greatly, and this qualification is practically of great importance, since starch is applied above all for the stiffening of linen ("starching"), for preparing bookbinders' paste, and for the finishing of the textiles. It is, therefore, of great importance to know the different temperatures

at which respectively the swelling and the paste formation of the various kinds of starch ensues, and the following table may serve as a guide:—

	Perceptible swelling.		Paste formation begins.		Paste formation becomes perfect.	
	Degrees according to					
	Celsius.	Fahr.	Celsius.	Fahr.	Celsius.	Fahr.
Rice starch	53.75	128.8	58.75	137.8	61.25	142.3
Potato starch	46.25	115.2	58.75	137.8	62.5	144.5
Maize starch	50	122	55	131	62.5	144.5
Wheat starch	50	122	65	149	67.5	153.5

In order to make a good starch paste, in an expeditious way, the starch to be used for the purpose is mixed with some water until it becomes a thick milky substance, and then pouring the same in the shape of a thin stream into a corresponding quantity of boiling water, which is to be kept in motion by constant stirring. This manipulation may also be reversed, and the same result attained thus: by diligently stirring the boiling water, while pouring the same gradually into the stiff and cold mixed starch-milk. In both cases the process of paste formation will be the same, but by applying dry starch this will not be the case. Starch paste decomposes when exposed to the air, even in an ordinary temperature, and is, according to the investigations of *Saussure*, transformed into sugar, gum, and other products. In the presence of gluten this decomposition takes place after the lapse of but a very few hours.

Relation of Starch to Acids.—Not less remarkable, and in a technical chemical respect even still more important, is the relation of starch to the various acids. In general acids, greatly diluted, transform starch into

dextrine (gum) and starch—or grape-sugar (glucose); while concentrated acids—especially when applied for an extended time—into diverse organic acids, as formic acid, glucinic acid, apo-glucinic acid, etc., and various other products of decomposition.

The relations of starch to oxalic acid, tartaric acid, and tannic acid, have also for many years been a subject of investigation, and especially *Anthon* has made a series of experiments respecting the relations which starch bears to silicic acid, from which we learn that starch, during a continued heating with this acid, will be but little changed, and a real formation of dextrine will not thereby occur. In a general way, we may therefore assert, that all organic and inorganic acids in diluted form, excepting only phosphoric, silicic, and acetic acids, will transform starch into dextrine and sugar; while at the same time the influence of acids on starch, according to their nature, their degree of concentration, and according to their action in an ordinary or a higher temperature, will be varying.

Relation of Starch to Diastase, Gluten, Animalic Liquids, etc.—Exactly in the same manner as diluted acids act, in a higher temperature, on starch, so also some other organic substances act on the same, thus especially diastase, mouth saliva, abdominal saliva, gastric juice, blood serum, gall, etc., by transforming the same into dextrine and grape- or starch-sugar (glucose).

Diastase, an azotic substance, soluble in water, and itself in a state of continual decomposition, and hence of a changeable composition, is formed from the protein substances of grain during their process of germination. It forms not only in malt, but moreover in all germinating seeds. The working of dias-

tase results best in a temperature of from 60° to 70° C. (140° to 158° F.). After it reaches 75° C. (167° F.) it decreases, and finally ceases entirely. Of this action of diastase good use is made in distilleries and breweries, while the action of the saliva of the mouth and abdomen produces the digestion of the starch in the animal system.

Relation of Starch to Bases and Alkalies.—The action of starch on alkalies is very singular. The latter possess, even in a cold and diluted condition, similar to the action of boiling water, the power to transform the amylum into a semitranslucent jelly, like a paste, while they more or less destroy the strata of the starch granules, and cause thereby an extraordinarily strong swelling of the same. If starch is brought in contact with a solution containing one and a half to two per cent. caustic potash or caustic soda, it will swell up seventy-five fold of its original volume.

This ability of absorbing alkaline liquids possessed by the starch granules, can be greatly increased by completely drying out the starch.

Ammonia (volatile alkali) causes no pasty formation. If to a solution of salts of ammonia a small quantity of starch is added, and also a few drops of liquid soda-lye, the starch will remain unchanged until the entire quantity of the ammonia salt becomes decomposed, but the single starch granules swell visibly as soon as a small surplus of soda is present. The alkaline solutions of starch can be precipitated by means of blue vitriol (sulphate of copper) in the form of a blue substance, which being soluble in pure water can be boiled without changing its color to black, wherefrom it follows that this precipitate consists of a composition of starch and copper, but it is not hydrate oxi-

dulated copper, which latter, as is well known, loses its hydratic parts by boiling, and then turns to a black color. This action of starch on copper solutions makes it possible accurately to determine the quantity of starch- or grape-sugar contained in any starch, since this action of the starch precipitates the copper in the form of hydrate of protoxide of copper.

Although *amylum* (starch) is generally considered as a neutral or indifferent chemical body, it possesses, nevertheless, the property to combine under certain conditions with several bases, as barium, lime, and protoxide of lead.

Relations of Starch to Iodine, Bromine, and Chlorine.—The relation of starch to iodine is very characteristic. Messieurs Colin and Gauthier made the important discovery, in 1812, that iodine with starch—just according to quantity and concentration of the solution of the iodine applied—will cause a compound of a carmine-red, violet, or transparent (also non-transparent) dark blue (with large quantities of starch), almost black colors, which is called iodine starch. Thus, iodine may be applied as a very sensitive test for starch (and the reverse). Particularly suitable for this purpose are the solutions of iodine in water, alcohol, or an aqueous solution of iodide of potassium. The peculiar action of iodine in coloring starch red, violet, or blue, does not merely bear upon certain parts of the starch granules, but upon their entire substance, and is so extraordinarily intense that in consequence thereof the *reaction* may be applied, not merely for discerning the iodine, but also the starch itself; and this can be done with great reliance in all cases, even when these substances are contained in any compound in but very minute quantities. A starch

paste, holding iodide of potassium of but 0.0000025 to 0.0000033 parts, will yet turn perceptibly blue, when for the purpose of disengaging the iodine it is mixed with common sulphuric acid containing some nitric acid. The various results of the test on starch, dextrine, and sugar with iodine furnish a reliable method of accurately pursuing the transformation of starch by the action of diluted acids, diastase, etc., into dextrine and glucose.

Bromine colors starch intensely yellow, while *chlorine*, on the other hand, bleaches it.

Fermentation and Decay.—Starch is not fermentable, and the opinion of those who deem it fermentable must be pronounced as decidedly erroneous. When even common sugar (cane-sugar), so easily soluble in water, cannot ferment without passing first through the condition of starch- or grape-sugar (glucose), how could such be the case with a substance like starch, which is not soluble in cold water?

On the other hand, starch, like all other organic substances, is subject to putrefaction, that is, decay, although in a lesser degree than various other matters. It becomes, when somewhat moistened, especially in stagnated air, easily musty, which, doubtless, must be looked upon as the first stage of decay. In general, however, it withstands this tendency with greater energy than most other vegetable substances, especially more so than the indifferent gum of plants, which is soluble in water, or the scum of sugar, and other vegetable substances, etc. But starch does very easily and quickly putrefy when it is previously freed of its organic structure, and when it has been transformed into a paste or solution. This subject of decomposition has already been the particular study of *Saussure*,

whose reports on this subject are even to this day of scientific and practical interest. Saussure proved that starch paste, when exposed to the air, in consequence of a *milk sugar* formation, turns sour; and that with the co-operation of gluten and similar substances it forms butyric acid, since a part of the starch passes through the process of butyric acid fermentation. During the process of putrefaction a considerable quantity of glucose is also formed.

SECTION II.

THE TECHNOLOGY OF STARCH. THE MANUFACTURE OF STARCH.

General Introduction.

For the manufacture of starch—without regard to what kind of raw material — it becomes above all necessary to make loose that part of the plant which surrounds the starchy matter. This is done by loosening the cellular tissues, by disaggregating the same, so as to make it possible to separate the starch granules, which are thus laid bare, by simply washing them out with water (removing the dross), and in this way breaking them off as thoroughly as is possible from all the other vegetable substances. Therefrom it follows, that from the theoretical point of view the manufacturing of starch still depends on naught else but a mechanical operation. In the practical production of this article, nevertheless, some chemical phenomena present themselves—this is particularly the case in the manufacture of starch from grain and especially wheat —which are caused by fermentation, putrefaction, and other transformations. Moreover, the process of loosening and separating the tissues—especially in the manufacture of starch from rice and maize—is aided by such chemical means as are best calculated to dissolve those substances which give to the cellular tissues their power of cohesion. The vegetable sub-

stance, removed either by mechanical power alone, or by the process of fermentation and other solving agents, is thereupon freed from the starch. This can also be accomplished by kneading, permitting the *fecula* to settle in the water, and after washing it drying it out.

We have previously said that thus far no plant is known which does not contain, during certain periods of its growth, some larger or smaller quantity of starch. And yet, despite all this, the number of those plants which yield sufficient starch for purposes of manufacture in quantities, is proportionately but small, and is limited both in Europe and America chiefly to potatoes, wheat, rice, and corn (maize). For the manufacture of starch on a larger scale, those vegetable substances only can be used which can be gathered in large quantities, and which, furthermore, permit of the process of separating the starch without difficulty, and of finally furnishing a product whose properties render it suitable for the different practical purposes. All bulbs and roots which contain an abundant amount of starch have a soft and tender tissue, and permit the separating of the starch without difficulty; while the obtaining of starch from seeds and fruits, on the other hand, is frequently more difficult, on account of the denser tissues and the trouble of removing the covering or opening the tissues. Larger quantities of gluten in seeds make it often very difficult to separate the starch from them, or cause it to be so expensive that a separation of the starch would not be remunerative.

In the United States starch is almost exclusively manufactured from potatoes, wheat, maize, and rice. Inasmuch as potato starch is cheaper to manufac-

ture than that made of wheat and maize, the last two are only applied for those purposes for which the former is really not advantageous. For the finishing of cotton and linen textiles, and for starching (stiffening) cloth, wheat starch is better suited than potato starch, since the paste made of the latter is too translucent; for paper-hanger's paste, and for the use of bookbinders, etc., wheat starch also serves best, because it furnishes a better sticking paste than potato starch. For the sizing of cotton and paper, for the manufacture of starch-gum, starch-syrup, and starch-sugar, potato starch may be applied, and for these purposes it is manufactured.

The yield of the article from a starch-containing substance, all other things being equal, is greater, where less cellular tissues of the substance remain closed during the process of working them, since no starch granules can be brought forth from the unopened cells. If means of loosening or freeing such granules from the cells were known, which would not injure the starch granules, we would be enabled to extract from every vegetable substance the entire contents of starch.

The primary condition for rationally establishing a starch manufactory is beyond controversy the possibility of a good location so as to have easy means of furnishing the raw material. Besides this first and most important requisite, the following should be likewise observed :—

1. Easy access to a sufficient supply of clear water, with drainage for the running off of the water used for washing.

2. That good turnpikes and highways, and a rail-

road or a navigable river are adjacent to the establishment, and thus the transport and traffic made easy.

3. That the necessary fuel (wood and coal) can be obtained at reasonable rates.

Of great influence upon the exterior appearance of the starch is the condition of the water, as regards its purity and colorless condition. If the water is muddy, the starch will settle with impure substances, and impart to the same a yellowish color; this also happens if the water is not entirely colorless, whereas a certain portion of the pigment thereof dries within the starch and thus reduces its whiteness.

Water of a brownish color, such as is often found in marshy or moorish ground, may, if it is otherwise clear, be applied for the first washings of the starch flour, but for the final precipitation it must be absolutely colorless, which may be secured by mixing it with some sulphuric acid or a solution of hypermanganate of potassium. Since, as has just been stated, the last washing only requires perfectly colorless water — whose quantity is not large—the cost pertaining to this mode of purifying is but very small, and repays by the higher price obtainable for entirely white starch, more than double. Some mountain waters too —especially when they hold in solution carbonate of lime—are also injurious to the nice appearance of starch, since the carbonate of lime and with it some coloring matter precipitates and discolors the starch. Such a water is best treated by adding sufficient muriatic acid, in order to neutralize the carbonate of lime thereby. In most of such cases 60 grammes (1.5 ozs.) commercial muriatic acid are ample for every hectolitre (2.8 bush's) of water. This can, as is obvious, be accomplished with very little expense. Under any

circumstances it would be best, should the lime be unavoidable, to have it in the form of chloride of calcium and not as carbonate of lime.

The Manufacture of Potato Starch.

In the first place we will turn our attention to the manufacture of potato starch, not alone on account of its general importance, but for the reason that it chiefly forms an agricultural occupation, *i. e.* that it may be combined profitably with farming and is carried on extensively in this way, while the production of other important species of starch, such as wheat, rice, and maize starch, forms each a separate branch of industry, and is generally carried on on a larger scale. This is explained from the fact that the potato, on account of its large contents of water, contains but from one-fourth to one-sixth of the amount of starch derived from wheat, maize, or rice, and hence does not permit of such extended transportation from a distance, and moreover does not admit of such long storage as the various species of corn. The process of making potato starch is a simple one, and frequently the housewife of a farmer makes a very good article by merely using a hand grater and a sieve.

The obtaining of potato starch requires such manipulation that the cellular tissues of the potatoes, which simply envelop the starch granules and moreover net-like, are to be dismembered by mechanical contrivances, whereby the starch granules are laid bare, and it becomes thus possible to separate these from the coarser, flaky, greatly swelled fibres, by the simple means of sifting.

One of the greatest difficulties attending the manu-

facture of starch from potatoes, is the transformation of the potato into the most possible uniform pulp without carrying on the process of bruising, and cutting up the cellular substance too far, which is unprofitable in several respects. In the first place, it should be considered, that thereby too much *fibrin* is ground so finely, that it also passes through the sieves, and thus lessens the yield of the first quality article; and secondly, because, by a too extended and energetic mechanical use of the grater, the covers which envelop the starch granules will be so affected that the value of the article for many purposes will be injured.

The Raw Material.

The potato (*Solanum tuberosum* or *Solanum esculentum;* English, *tuberous potato;* French, *pomme de terre;* German, *Kartoffel*) is undoubtedly one of the most important and useful plants arising out of our agricultural pursuits. According to the richness of the soil in which potatoes are planted, and to more or less favorable weather, the yield of potatoes is regulated, and on these circumstances also depends the quantity of starch contained therein. The potatoes contain in their cells only liquid matter (sap) and starch granules. The juice or sap is essentially an aqueous solution composed of albumen, gum, and diverse salts. The amount of starch in the potato is very fluctuating, and may rise above 25 per cent., but may also fall below 15 per cent. The substance of which the textures of the cells are composed is the cellular tissue of plants (cellulose); but the cellular substance of the exterior layer, the skin, is a corky substance distinguished by its imperviousness to water.

The average chemical composition of good potatoes can be expressed in percentage, as follows;—

Starch	20.00
Epidermis, cellulose, pectine, pigment	1.65
Albumen and other azotics	2.13
Fat	0.11
Sugar, resin, and volatile oil	1.06
Salt and ashy ingredients	1.06
Water	74.00
	100.00

The many analyses have proved that the starch contents vary greatly, not only in the different species of the potatoes, but are even not always alike in the same species. They vary according to the state of the soil they are planted in, and the influences of the prevailing weather and climate during their growth; and in no less degree also on the fertilizer used for making the soil richer.

The suitable storing (housing) of potatoes is for the manufacturer of starch of the greatest importance, so that the potatoes are thereby protected against the rot, freezing, and germinating (sprouting)—a calamity which not only influences the quality, but also the yield of starch, yea, under certain conditions will render the potato entirely unfit for the production of starch.

By storing potatoes in well-constructed bins, silos, or cellars which admit no frost, their contents of starch can be entirely preserved, whereas frost and sprouting, as well as the rot, will materially lessen their value for technical purposes.

Determining the Amount of Starch in Potatoes.—The knowledge of the amount of starch contained in the potato is of vital importance to the manufacturer of starch. This amount of starch can only be judged

aproximately and empirically from the condition which the potato attains after boiling. The drier (mealy), and, so to say, the more "*crystalline*" shining, it in that state appears, the richer it will be in starch; while, conversely, a lesser content of starch may be counted on, the more watery and transparent the boiled substance appears. It must, however, be understood that such a method is not at all suited for even an approximate determination of the starch value of potatoes. But quite different are the relations of the amount of starch in the potatoes toward the specific gravity, which depends on the principle that all solid ingredients (dry substance) of the same are of a specific gravity greater than water; and, on an average, two-thirds (according to the quality of the potato, fifty-five to seventy-six per cent.) of this entire dry substance are placed to account of starch. We can, therefore, take it as a rule, that the potato must have a larger specific gravity the greater its amount of starch. The finding of the specific gravity of the potato may be accomplished in various ways, and we will here elucidate some methods. Before we, however, consider these various methods, we will state, by way of general remark, that, from the determination of the specific gravity of a few potatoes, no conclusion as to the average amount of starch in the whole can be formed, since experience has proved that the single parts of a heap of potatoes are very often very varying in their specific gravity. Hence it will be necessary to determine always the specific gravity of a greater quantity of potatoes, and thereupon calculate the value of the material.

A very convenient method for determining the specific gravity of potatoes has been suggested by *Fre-*

senius and *Schulze*, and by their method the determination of the amount in potatoes of dry substance and starch has become very convenient for technical purposes. Their method rests upon the well-known physical law, that a body which floats in a liquor in such a manner that it neither appears entirely upon its surface nor sinking under, possesses a like specific gravity with the liquid itself. Resting on this circumstance, the determining of the specific gravity of the potato is carried out by the method of *Fresenius* and *Schulze*, as follows:—

A concentrated solution of common salt is prepared of about three parts of water to one of salt; a wide vessel or glass is filled to one-half of its capacity with water, and the potato to be examined is placed therein, which, on account of its greater specific gravity, sinks to the bottom. Thereupon, some part of the concentrated salt solution is poured into the glass, while constantly stirring, till the potato, resting upon its bottom, gradually rises up, and finally remains floating in the liquor. By determining the specific gravity of this salty fluid thus made, you have also, by means of a saccharometer, the specific gravity of the potato. If we now desire to ascertain the starchy value of the potato, nothing remains to be done but to look for the same figure contained in the index given below, which, as indicated by the hydrometer, gives the specific gravity of the salty fluid, respective of the potato, and the figure thus found is the specific weight of the potato analyzed.

In carrying out this experiment, care is to be taken that no air-bubbles adhere to the potatoes. Should this be the case, they can be easily removed by the feathery part of a goose-quill. If the potatoes are

moistened all over with water previous to placing them in the glass, such bubbles will not appear. Care should also be taken that the liquid for determining the specific gravity, by means of the saccharometer, retains the same temperature which it had while the potato was floating therein.

Table for ascertaining the Specific Gravity of Potatoes, founded upon the degrees indicated by the Saccharometer.

Degree of the saccharometer.	Specific gravity.	Degree of the saccharometer.	Specific gravity.	Degree of the saccharometer.	Specific gravity.
14½	1.056	20	1.083	25½	1.108
15	1.061	20½	1.085	26	1.110
15½	1.063	21	1.088	26½	1.113
16	1.065	21½	1.090	27	1.115
16½	1.068	22	1.092	27½	1.118
17	1.070	22½	1.094	28	1.120
17½	1.072	23	1.097	28½	1.122
18	1.074	23½	1.099	29	1.125
18½	1.077	24	1.101	29½	1.127
19	1.079	24½	1.103	30	1.129
19½	1.081	25	1.106		

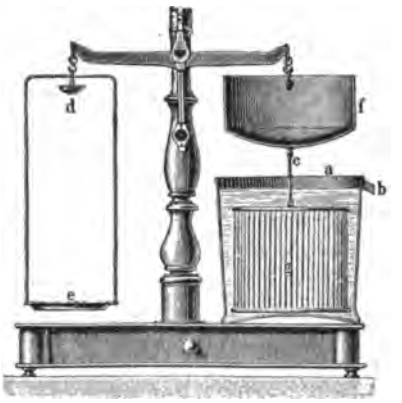
Supposing now the saccharometer, when placed in the salty solution, had indicated 19½°, the specific gravity of the solution, and hence also that of the potato, would be 1.081. But should the saccharometer, for instance, show 19¾°, the specific gravity of the potato, in this case, would be $\frac{1.083 + 1.081}{2} = 1.082$.

It is evident that the specific gravity can also be determined in a more direct way, by the aid of a hydrometer (which shows the specific gravity on its scale), or by weighing in a flask which holds one hundred grammes (3.5 ozs.) of water, so that in such a case the above table can be dispensed with.

Fesca has, for the purpose of determining the specific gravity of potatoes, constructed a particular scale, by

means of which five kilogrammes (eleven pounds) of potatoes can be weighed at once, and a very accurate determination of density can be obtained. This scale is arranged as delineated in Fig. 1.

Fig. 1.

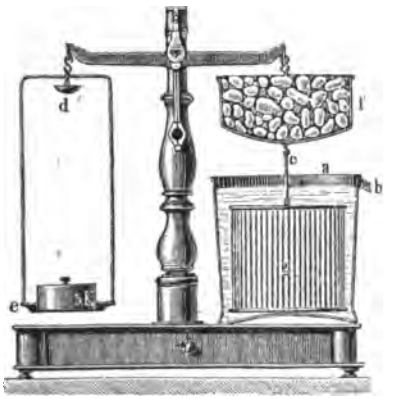


Fesca's scale for determining the specific gravity.

The vessel *a* is filled with water, until the latter runs over and out of the tube *b;* thereupon the wire basket *g* is withdrawn from the scoop *f* near *c*, and is repeatedly thrust upon the bottom of the reservoir *a*, in order to remove all the air-bubbles which now adhere to the wire basket, and the scales are balanced by placing small weights on the scoop *d*. Now, a five kilogramme (eleven pound) weight is placed upon the basin *e*, and the five kilogrammes of potatoes which are to be weighed are, after they have been first thoroughly brushed off, placed in the basin *f*, but care must be taken to prevent the potatoes from falling into the vessel or basket *g*. In order to bring the scales into perfect balance, the last potatoes are placed in singly, and, if necessary, pieces are cut off from one or the other of the potatoes, in order to obtain exactly

five kilogrammes (eleven pounds) of potatoes. By this operation but one cut surface should remain on any one of the potatoes (Fig. 2).

Fig 2.



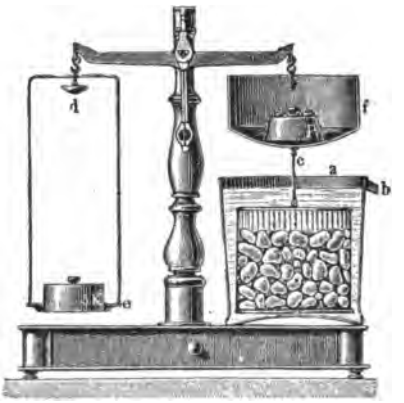
Fesca's scale for determining the specific gravity. Second operation.

In order to find the weight of these five kilogrammes (eleven pounds) of potatoes in the water, or rather to find the weight of the water displaced by the potatoes, the potatoes are now taken from the scale *f* and placed in the wire basket *g* (without removing the five kilogramme weight or the adjusting weights) replacing the weight in the scale *f* as much as is necessary to balance the scales (Fig. 3).

Whereas now every substance placed in water weighs so much less as the water of a like volume displaced by such substance amounts to, the weights placed at *f* for counterbalancing are equal to the weight *P* of the water displaced by the five kilogrammes of potatoes. This weight fluctuates between 4.421 (9.726 pounds) and 4.717 kilogrammes (10.377 pounds), but is accurately ascertained by the use of suitable weights, even to the fraction of .001

kilogramme (.0022 pound). The specific gravity of the potatoes is obtained through the division of the

Fig. 3.



Fesca's scale for determining the specific gravity. Third operation. Determination of the weight of water displaced by the potatoes.

weight of the potatoes (five kilogrammes) by that of the displaced water (P), and hence is equal to $\frac{5}{P}$. In order to obtain correct results the following rules should be strictly observed: Prior to transferring the potatoes from the bowl f into the basket g, they are washed and brushed clean. This is done in order to moisten every part of the potatoes in such a manner that no air-bubbles can adhere. Thus moistened, the potatoes are placed, one after the other, in the wire basket. Should some of them be found lighter than water, then they are to be covered by the heavier ones, so as to cause them to remain under water. The potatoes must be entirely covered by water. The water to be applied must be rain or distilled water; potatoes and water must be of the same temperature as the room is where the operation takes place, and hence they ought, previous to being weighed, to be placed in that

room. The water reservoir and the scales have to be placed so that the wire basket does not touch the sides or the bottom of the former.

The Manufacture of Potato Starch.

For producing starch from tubers generally two methods are known, which essentially differ in principle. The first method, more commonly applied, which is known as the "*older method*," consists of the grating of the tubers into the finest possible parts, by means of graters or such like apparatus. A fine pulp is prepared, washed out in sieves, or rather brushed through the meshes of the sieves, while allowing the free flow of water through the same, and thereby separating the starch from the drained-off milky liquid. The starch obtained in this simple manner is thereupon purified, either by washing it out or by applying centrifugal force for cleansing, then dried in drying-rooms, where a high degree of temperature is maintained, and, finally, the substance is crushed (bruised) between rollers.

The second method, known as *Voelker's process*, consists in first opening the cellular tissues of the tubers in a chemical way. For this purpose the potatoes are first cut in slices, macerated in tepid water, then piled up in heaps of several feet high, and thus left undisturbed for about eight days, whereby the temperature increases to about 40° C. (104° F.). In consequence of this spontaneous heating, in fact, putrefying of the potatoes, some chemical transformations occur in the tissues of the tubers, which have not as yet been sufficiently investigated, but they undoubtedly result from the formation of a matter, which not only dissolves the intercellular substance of the starch-containing tissue,

but also affects the cellular textures and partly dissolves them. This is probably caused by the formation of organic acids ensuing during this process, and which dissolve the intercellular substance which is composed of pectine bodies. The chemical process, however, which causes the solution of the cellular textures is still entirely problematical, as this chemical process has not yet been thoroughly investigated by scientific men. The putrefaction having amply progressed, and the fibrin having lost its cohesive property, in so far as to transform the potato substance into a soft dough-like mass, then a complete separation of the starch by mechanical means may be carried on with ease. To this end, the substance, which beside starch also contains fibrin and skin (forming a paste-like, loose mass), is mixed with plenty of water, and strained through a coarse sieve, whereby the coarsest parts are retained. The separating of the finer parts is thereupon caused by application of fine hair or wire sieves, whose meshes are so fine as to pass only the finest starch and finely broken up fibre parts. The separating of the starch from the fibre parts is finally accomplished by the application of a very ingeniously constructed washing apparatus.

We will now consider these methods of manufacturing starch in detail, as applied in practical usage. The fabrication of potato starch by the older method is divided into the following operations:—

a. The washing of the potatoes.
b. The grating.
c. The washing, separating the starch from the pulp.
d. The washing out and refining of the starch.
e. The drying of the starch.

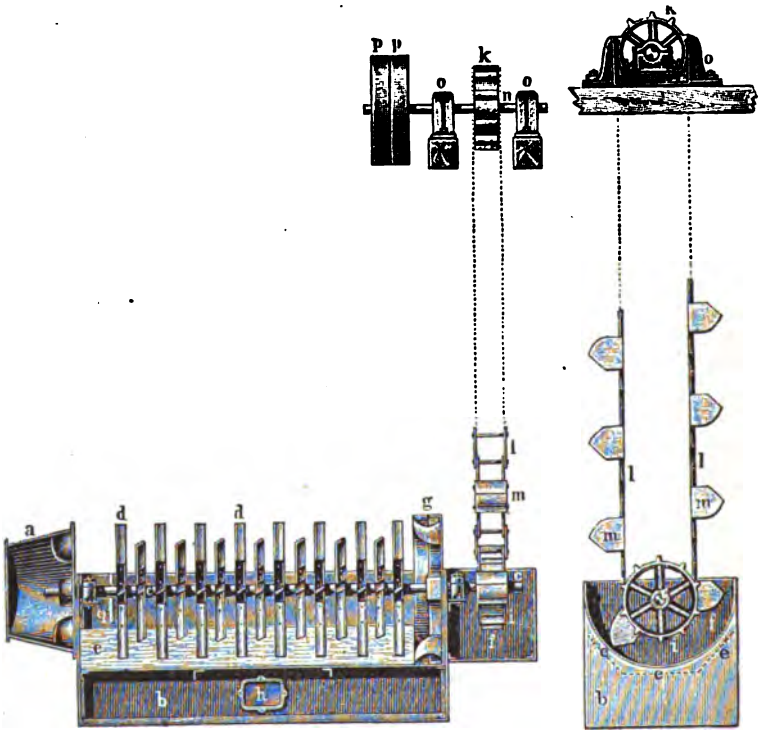
The Cleaning of the Potatoes.—The potatoes are washed, in order to remove earthy substances and small stones which adhere to them, and are frequently of the same shape and color as the tuber, but very injurious to the grating machine. This cleansing is easily accomplished when the potato grows in a sandy soil, but it is more difficult and requires much time when the potatoes were raised in a heavy clay soil, as the tubers will then have on their surface many deep penetrating points (tubercles). The removal of the slimy earth particles must be carefully done, since they not only injure the quality of the starch, but also lessen the yield of it as a first class article.

In all of the larger starch-manufacturing establishments an apparatus is expressly in use for this purpose, in the form of a cylinder. Of these contrivances there are quite a large variety, but we select for our use and delineation one of the latest and of the best construction.

Venuleth's washing-machine (Figs. 4 and 5) is an excellent apparatus, by means of which part of the dross is removed from the potatoes by the process of dry-sifting. It consists of the following parts: *a*, A conical iron-drum, provided with a basket for transmission; *b*, a long square iron case with beds for the strong iron shaft *c*; *d d* are the cross-branches supplied with wooden beaters; *e e*, the iron grate, composed of three parts, so as to be able to take it out when cleaning the entire machine; *f* is a semicircular box for receiving the washed potatoes; *g* is the wheel for drawing up the water (bucket wheel), and by which the washed potatoes are dispatched to the box *f*; *h* is an opening for the flowing out of the wash and waste water, worked by a slide with a handle.

Venuleth's apparatus is, as is shown by Figs. 4 and 5, supplied with an elevator (endless chain with pump-work), which makes it possible to send the washed potatoes, without the use of manual labor, in a direct

Fig. 4. Fig. 5.



Potato washing-machine with elevator.

and continuous way to the grating machine in the upper story. The elevator itself consists—for the working of the elevator-chain and washing machine—of a lower wheel, *i*, and an upper elevator-wheel, *k*. By *l l l* the elevator-chain is shown, while *m m m* represent the pump boxes, which latter are filled at *f* with potatoes, in order to re-deposit them above directly

into the hopper of the grating machine; *n* is the counter shaft; *o o*, two movable beds to tighten the elevator chain; *p p*, "fast and loose belt drums" (pulleys) for moving the machine. In further describing this machine, we notice in front of it the board *g* which is inserted into the apparatus. By this board the potatoes are at once caused to sink below the surface of the water, immediately after their reception in the washing box, since all the potatoes can only enter the actual space for washing, through the opening situated under this board. During the process of washing, the potatoes are placed in the preparing drum *a*, where they are sifted in a dry way, and in this manner are already freed from a large part of the earth adhering to them. From the preparing drum, they are forwarded to the washing box, where they are "beaten" while water is constantly flowing in; from thence they are gradually pushed into the drum *g*. Meantime, the stones, gravel, sand, and dirt sink to the bottom, and can be removed from the box through the opening placed therein for this purpose.

The washed potatoes fall from the ejecting-box into the semicircular storage-box, *f*, and are there received by the small elevator-cases, *m m*, and sent up to the grater.

The greater the care taken in washing the potatoes, the nicer and whiter will be the starch produced from them; otherwise it would be almost impossible to remove the earthy particles—especially the red or gray colored dross—which might mix with the starch and with the same precipitate to the bottom of the vessel used.

Grinding (grating) of the Potatoes.—The grinding or grating of the potatoes disrupts the cellular tissues, wherein the starch granules are situated, and thus lays bare as far as possible the starch substance. This task, however, can never be perfectly accomplished by a mechanical operation, and should for many reasons, which we will mention below, never be attempted. Notwithstanding this, the general opinion prevails, that the finer the potatoes are grated the more cells are opened, and the greater will be the yield in starch. Hence, the grinding-machine is the most important apparatus for the manufacture of potato-starch. That the machines at present used for this purpose, do not completely and satisfactorily fulfil it, becomes manifest, since all starch manufactories do not use the same machine for grating.

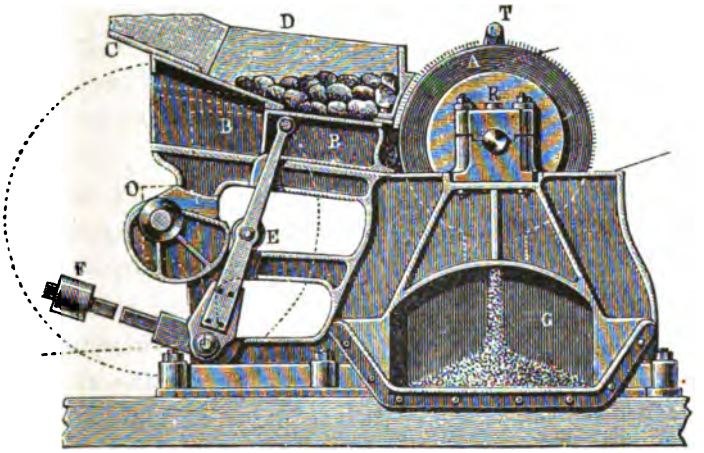
The machines used for the grinding of potatoes are of various sizes, and quite a number of such contrivances are in vogue, from the simple hand grater to the latest construction of Champonnois, whose "grater" is at present the best known one.

The working capacity of this grater amounts in 24 hours to a production of about 25,000 kilogrammes (55,000 lbs.) of potatoes. Wherever a homogeneous mass is desirable the application of this machine will be of the greatest advantage.

By means of the eccentric *O*, which by turning presses against the wheel belonging to an extension of the lever *E*, a rapid back motion of the buffer *B* is accomplished; the forward pushing of the same and the pressing of the potatoes against the grater are performed by means of the weight *F*, whose pressure can be increased or decreased, by displacing the parts of the lever. This is regulated according to the con-

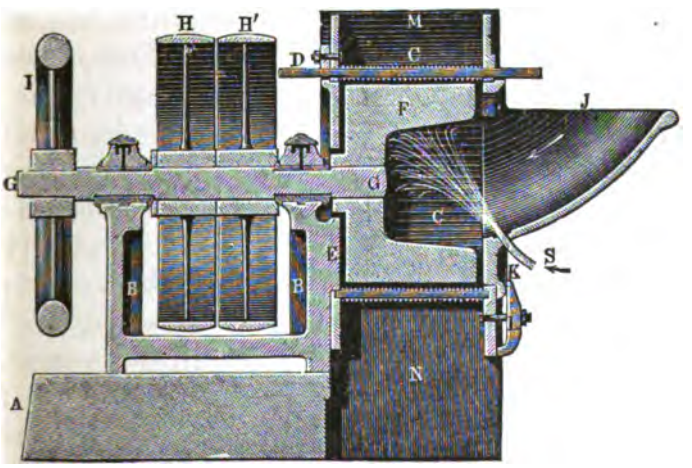
struction of the teeth of the saw, or the nature of the potatoes.

Fig. 6.



Champonnois's grater with mechanical buffers.

Fig 7.



Champonnois's grater of latest construction.

The potatoes are placed in the mill-hopper *J*, the two flyers *F F* revolve with a velocity of from 800

to 1000 revolutions per minute around the axis *G*, take hold of the potatoes and force them with the velocity of their rapid turning towards the teeth in the drum, whereby they are macerated and changed into a fine paste. The points of the sawblades are very short, and extend but 0.5 mm. (0.020 inch) above the drum-surface. During their use, they become after a short time bent, inasmuch as the potatoes are incessantly hurled with great velocity against them, and always in the same direction. For this reason, the shaft is allowed to run in a reverse direction—after the grater has run for half a day or so—and thus forcing the potatoes against that side of the teeth which have previously been bent. After 48 hours' use, the teeth usually become entirely dull and must be resharpened.

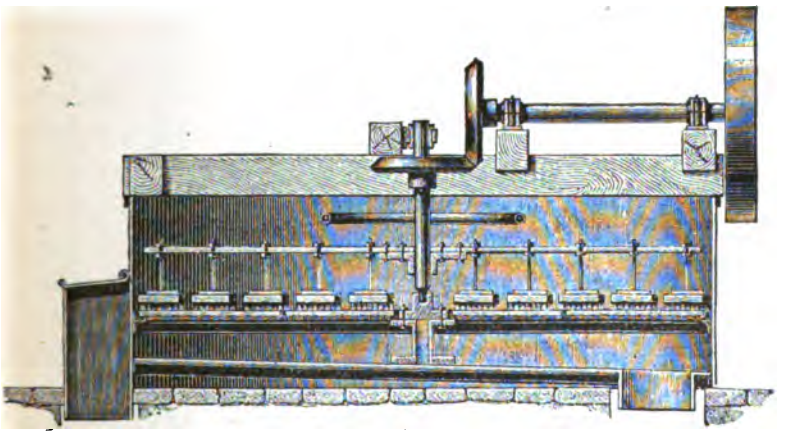
Finally, it should be mentioned that great care must be taken to keep the grater and reservoir absolutely clean. This is of the utmost importance; remnants should never be allowed to remain long in the box, since in this finely divided paste, on account of the influence of the atmosphere, a decomposition will soon ensue. It will be profitable to apply the smallest possible receiver, which compels the workmen to perform a quicker operation in shovelling away the grated potatoes thrown out by the machine. Both grater and receiver should be thoroughly cleaned every six hours, and be washed out with clear cold water, and thus prevent sourness.

The Operation of Washing (*Sifting*), *Separating the Starch from the Paste.*—The paste furnished by the grating consists of diluted fruit-juice (sap), freed starch-granules, cellular substance and fine fibres of potato substance whose cells have not been opened by the grater, which hence still inclose starch-granules. For separating the starch-granules, *i. e.*, loosening the

starch from the cellular substance, sifting apparatus of the most varied kinds are used, in which the paste is treated while water is constantly pouring on. The starch-granules pass through the meshes of the sieve, while the fibrous substance—the so-called pulp—remains in it.

The most simple apparatus of this kind, which is, however, merely used for manufacturing starch on a limited scale, consists of a common sieve of fine meshes either of wire or horsehair, which is placed in a tub or box filled with water. The sieve rests on two ledges fixed in such a manner as to give the sieve an inclined position, so as to be enabled to push the same into the water, or by turning to raise it up at will.

Fig. 8.

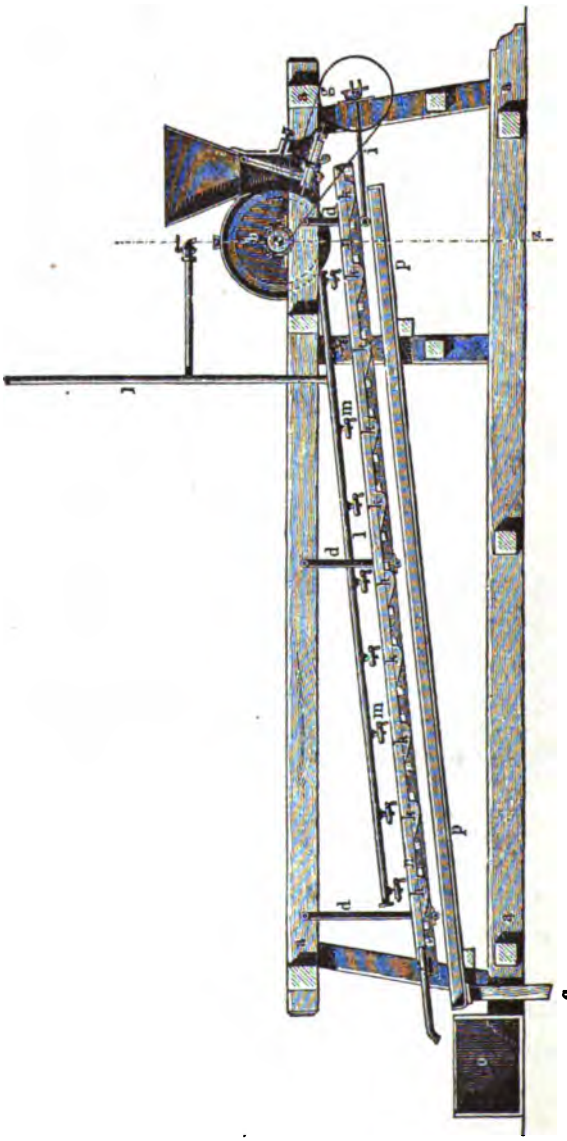


Cylinder sieve with brushes.—Seeles & Co. constructors.

The paste is put in but small portions into the sieve, and worked either by hand or by means of brushes, and alternately above or below the water, until by the pressing out of the residuum, starch no longer appears in the drained-off water. The starch

Fig. 10.

Fig. 9.



Siemens's Bolting-sieve of latest construction.

sinks rapidly into the water, or rather into the greatly diluted vegetable juice, so that a large quantity of the grated paste can be washed out before a renewal of the water becomes necessary.

As for this manipulation too, a great number of machines have been in use, most of which were more or less defective. *Siemens* invented the *bolting-sieve.* He has improved the apparatus of older construction so completely, that neither with regard to the water-supply, nor with regard to the washing of the potato-paste does this sieve leave anything to be desired.

In Figs. 9 and 10 we present Siemens's bolting-sieve of the latest construction, both in longitudinal and lateral section (diagram).

Upon a simple wooden framework *a*, the grating cylinder *b*, is fastened, from which the potato-paste falls directly upon the jolting sieve or bolting apparatus *c c*, which by means of bars *d d d*, is connected with the framework. The grating cylinder receives its motion from the driving pulley, *e* (*é* is the loose pulley). The roller *f* transmits the motion of the cylinder to the pulley *g*, and through this crank spindle *h* is set in motion, which by means of the bar *i* is in connection with the shaker-sieve.

The advantages of Siemens's shaker-sieve are essentially the following: Through the cavities of the boxes placed upon the sieve, a pushing together (accumulation) of the potato-paste upon the surface of the sieve is avoided, and moreover a large waste of water is prevented, since this no longer uselessly—as was formerly the case—runs off over those parts of the sieve which are not covered with paste. By the use of this apparatus the paste in the cavities forced by water will help to cover evenly the surface of the sieve

whereby the too rapid flow of the water through the sieve becomes almost impossible. Such an apparatus with a sieve of 3.3 metres (10.8 feet) length, and 30 centimetres width (11.8 inches), consisting of eight pieces of sieve and as many boxes, is sufficient to completely wash out the paste of from 400 to 500 kilogrammes (880 to 1100 lbs.) of potatoes per hour. In order to increase the yield of starch from potatoes, Siemens makes use of stone rollers, which revolve with unequal rapidity, and thus operate in both *bruising* and *grinding*. The paste runs off from the shaker-sieve, and the freed starch, in greater part already washed out, can be conducted into the receiving tank, while the former is crushed very fine by the rollers, and thereupon conducted to the so-called extracting machine upon which its total exhaustion is rendered complete.

The Edulcoration and Refining Process.—The starch separated in one or the other way from the potato, sinks in the liquid—a diluted fruit-juice—rapidly and settles upon the bottom, so that the brownish liquid may be soon, and moreover completely, drawn off. But in this condition as the starch deposits itself in the tanks or walled-in cisterns (*Sedimenteurs*), it is by no means yet pure, but contains impurities such as particles of clay, finely divided cellulose, etc., and chemically mixed with various other substances, as albumen, slime, rosin, fat, etc., from the potatoes. These impurities, which in the solid deposit of the starch are contained in but proportionately small quantities, are partly soluble in water alone (as albumen, slime) and others indissoluble, so these may be extracted with alcohol and ether (as rosin and oil). These latter substances, which are only soluble in alcohol and ether, impart to the starch the objectionable property of becoming, after

drying, a firm coherent mass, while starch completely free from these admixtures (rosin and oil), in the process of drying, would of itself break into a fine powder.

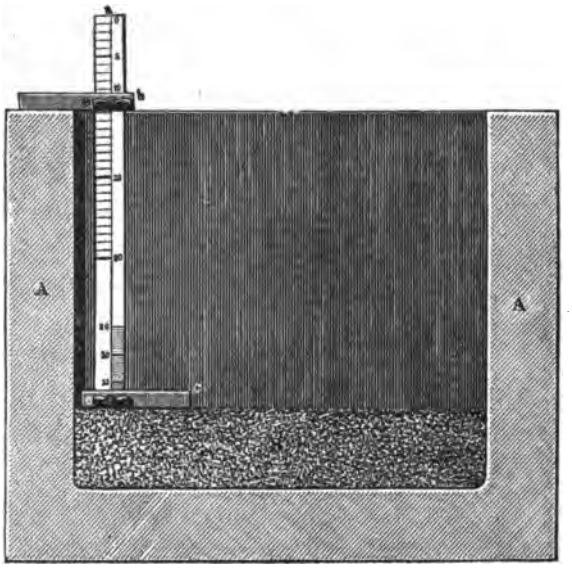
The washing, as also the edulcoration of the starch, however, is not generally to be extended to the removal of the substances which are not soluble in water of which there is only a very small quantity, but it suffices simply to thoroughly remove the common admixtures, and those impurities which are easily soluble in water. The latter are extracted simply by repeatedly renewing the wash water and are thereby removed in solution, while the common admixtures in consequence of their inferior specific gravity, or their finer particles, form a scum which may easily be taken off by stirring up with water the deposited starch, upon which, in the first place, these particles settled.

After the starch has sufficiently deposited itself in the "*Sedimenteur*," the water standing over the starch —containing salt and albumen—is drained off, and the thick starch-substance conducted into a large starch-washing tank (Laveur), the empty space remaining filled up with pure water. In order to ascertain the correct quantity of water necessary for this purpose and to obtain a starch-milk which is neither too thick nor too thin, the height of the starch strata in the "laveur" is first ascertained and thereupon filled up with water to the third part of the ascertained height. If, for instance, the height of the starch layer is 33 cm. (13 inches), the quantity of water to be allowed to flow upon the starch is $\frac{3}{3}^{3} = 11$ cm. (4.33 inches), height.

To do this efficaciously a simple measuring apparatus has been constructed by Markl, the use of which may be easily learned from our representation (Fig. 11).

On the ends of the measuring-gauge, which is of the same height as the "laveur," are two movable ledges, which by means of screws can be fastened. The gauge is from above to below divided and numbered

Fig. 11.



Markl's apparatus for measuring the height of the starch-strata in the tank.

into equal degrees, for instance into centimetres. The same numbering commences from below; but the single divisions are but one-third as large. If the gauge, as is delineated in the illustration, is sunk down to the level of the starch, and the upper ledge brought down to the top of the laveur, the extending space of the ledges will show upon the scale the height of the starch-strata in centimetres. It is then only necessary to push the lower ledge up to the same figure, and fastening it by drawing the screw tight, you can thereupon admit the flow of water, until the water level is of equal

height with the upper surface of the lower ledge, which is, for convenience sake, painted black.

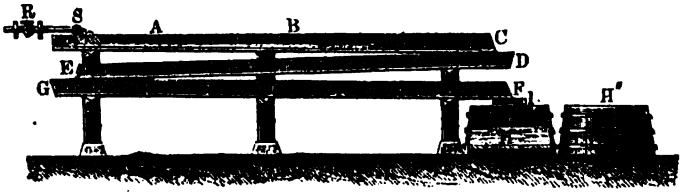
Another method for cleaning the impure starch, consists in stirring the same in a tank filled with water, which is supplied with a stirring apparatus, and by draining off the milky liquid by means of a spigot in a thin stream, and leaving it to flow through long slightly inclined gutters (so-called elutriating chines) of about 60 centimetres (23.6 inches) in width and 16 centimetres (6.3 inches) in depth. This can also be accomplished with still greater facility, by running the starch upon the upper part of the gutter and pouring water over it through the same watering apparatus, which is provided with a finely perforated spout. While the very thin starch-milk—produced in one way or another—flows over the inclined plane, the denser starch will deposit itself near the tank, at a greater distance, a less pure article, and the specifically lighter substances will reach the end of the gutter, and there drain off with the water. By applying thumb-screws, the incline of these gutters may be regulated.

The construction of such an *inclined plane* (elutriating machine) is sketched in Figs. 12 and 13.

The gutter has a slight incline of about 1½ millimetres (0.06 inch), per metre (39.37 inches) in length. Underneath this gutter two more gutters, *D E* and *G F*, of the same length and of the same incline, are placed, of which the middle one is fixed to run in an opposite direction, the lower one (*G F*) in the same direction as the top one. From a very finely perforated metal plate (rose), *S*, a fine jet of water is continually flowing —by opening the cock *R*—on the accumulated starch. The cock is situated at the upper end of the top gutter

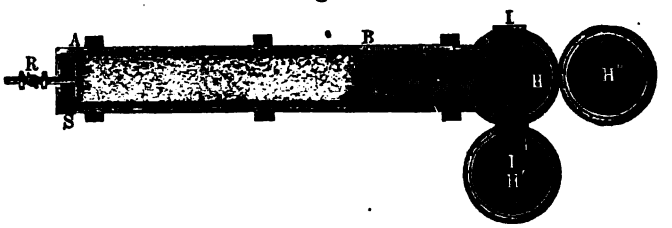
(*A*). The starch is continually stirred with a rake. The water will gradually carry off all the starch, and in consequence of its running smoothly and slowly will again deposit the pure starch in the gutters *D E* and

Fig. 12



(Side view.)

Fig. 13.



(Front view.)

Inclined plane (elutriating machine) for refining the slimy starch, etc.

G F, while the lighter particles remain suspended in the water, and along with some starch finally flow off through the gutters *J J*, into one of the tanks, *H H* or *H''*. In these tanks all will be redeposited in layers, whatever the liquid has carried off, and from this deposit the pure starch may be easily separated. and the muddy dross starch which again accumulates be refined by repeating the operation on the inclined plane. The refining of starch by means of the inclined plane is so convenient and requires so little labor and outlay, that in modern times, in most of the larger establishments, these described inclined planes find general application,

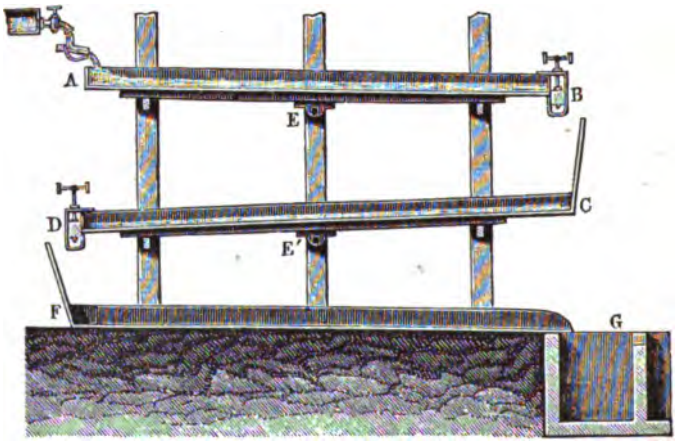
in lieu of tanks, for the washing and refining of starch. By a manipulation of 200 hectolitres (567.500 bushels) of potatoes in twelve working hours, a gutter of 80 metres (262.4 feet) in length, and 1.1 metre (3.6 feet) in width, with an inclination of from 1 to 1.5 millimetres (.039 to .059 inch) per length metre (3.28 feet) is required. For greater convenience the gutter is divided into three parts of equal length, as is shown by Fig. 12, and these parts are placed above each other.

The lower part, *F G*, of this gutter is placed on the ground floor of the factory, and is either neatly walled in cement or inclosed by a layer of asphaltum. The middle section of the gutter, *D C*, is of wood, as also the upper one, *A B*. The two upper gutters have for a foundation a strong timber frame, and their corresponding distance is the same as that between the lower and middle gutter, equal to 60 centimetres (1.97 feet). The incline of the two upper gutters can be regulated at will, and to this end serve the axes *E E'*, of the gutters, which rest firmly on the timber frame. The gutters can be turned around these axes to suit, and by dint of a greater or less incline, which is imparted thereby to the gutters, the flow of the liquid in the same may be accelerated or retarded. For regulating the level of the liquid in the gutters, the valves *B* and *D* serve; this becomes requisite as soon as a certain quantity of starch has been deposited in the gutters.

The working of this apparatus is very simple. The starch-fluid—sufficiently diluted with water—flows from a receiver by *A* to the highest part of the top gutter. The further motion of the liquid ensues very slowly, so that the heavier starch is deposited into the

upper gutter, while the lighter fibres remain suspended, and flow on, over gutters *C D* and *F G*, and empty into the cistern *G*.

Fig. 14.



Inclined plane for refining starch. (Longitudinal section.)

Hence the greater part of the starch is deposited in the upper part of the gutters *A B*, which for this reason must be cleared after each twelve working hours; the middle part, *C D*, is cleared but twice a week, the lower part, *E F*, but once in every week, since in these parts the starch collects but very slowly. The starch as taken from the gutters, although sufficiently pure for some commercial purposes, is, on account of the small quantities of *fruit-sap* still adhering to it, generally preferred to be washed out again with pure water in the depositing tanks. This last process of refining, is however accomplished much easier and requires a much less number of "*Sedimenteurs*,"—six to eight are amply sufficient—with the application of the inclined plane. Formerly, when the above described machinery was not yet known, the starch manufactories re-

quired for the refining of starch quite a large number of tanks which not only used up much space, and were also very expensive, but moreover necessitated much labor and it caused a great deal of inconvenience to keep them clean and pure. In recent times centrifugal machines or conical drums have been constructed for the refining of starch, which *Fesca* terms "*Refining Centrifugues.*" The inventor, Albert Fesca, discovered first, that, from the starch milk in the process of centrifuguing, the substances suspended therein will deposit themselves on the sides of the drum by turns according to their weight and specific gravity, *i. e.*, at first the larger starch granules, then the smaller, and finally the dross and fibrous substance, in such a manner that the latter forms a strictly separate layer which may easily be taken off from the white starch strata. The centrifugue may thus serve not merely for draining off the water, but also for purifying the starch. Fesca's refining centrifugue distinguishes itself from the common centrifugues by its drum being inside, divided by means of diametrical partitions into six sections, into which suitable boxes are placed which correspond to the sides of the drum, and are lined with cloth. During the centrifuguing of the starch-milk in this apparatus, six starch cakes will be formed in the box-shaped insets from which, after they have been taken out, the scum may be conveniently removed. In order to facilitate the placing in and withdrawing of these boxes from the drum the upper edges of the same are not riveted but screwed on. Every centrifugue is furnished with two drums, both of which fit upon the axes, and while one of the same is put in place and in operation, the other is being

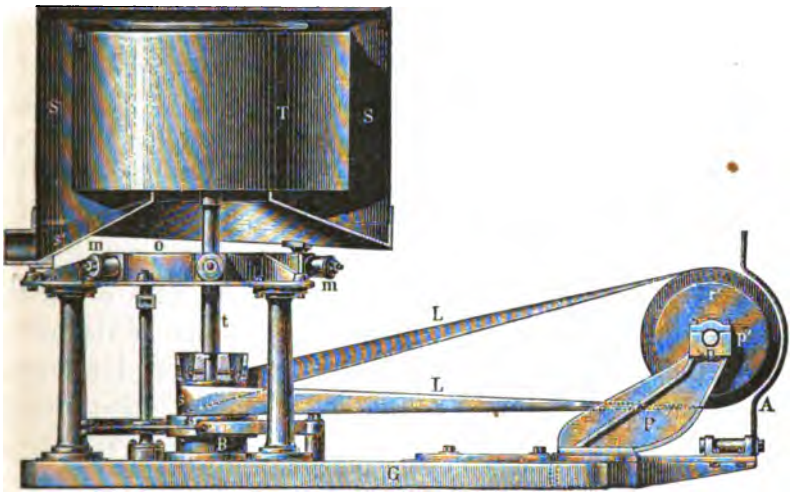
emptied and again prepared for the purpose of centrifuging.

The construction of centrifugues generally is essentially as follows: On the upper end of a vertical spindle a drum of copper or sheet-iron open from above is fastened, upon its bottom is riveted a cone of copper or cast-iron, while the sides of the drum are perforated and supplied with a double sieve of brass wire, the outer sieve being coarse while the inner is of finer texture. By means of turning the spindle the drum is put into swift rotation, and during this operation the starch mixed with water is placed therein. The mass descends in the first place upon the cone which extends into the drum, but immediately thereafter, in consequence of the centrifugal power, is hurled from the surface of the cone in all directions against the surrounding sides, and equally distributed in thick layers. By a continuous and rapid revolution of the drum, the liquid part (the water) of the starch flour is hurled or pressed through the meshes of the sieve, while the solid starch granules, which cannot pass through the finer sieve, are kept back. The water which is hurled out with great vehemence is caught by a casing (jacket) of iron plate which surrounds the inside drum and from thence is conducted out.

In order to secure for the centrifugue a successful action, a quiet motion of the same without rocking to and fro is absolutely requisite. This condition will be most perfectly accomplished by fixing the entire mechanism for motion beneath the apparatus. The spindle of the drum is so arranged as to move in the hollow (indentation) of a sphere, and by a so-called buffer-bed guide will yield in every direction to the pressure. The axis will thereby be enabled to cause

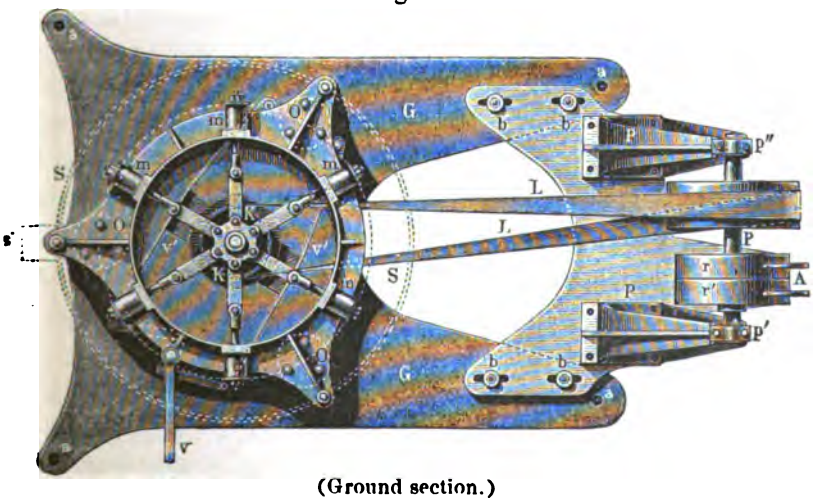
the centrifugue when in motion to choose its own direction, which may correspond to the eccentric course of its point of gravity.

Fig. 15.



(Vertical section.)

Fig. 16.



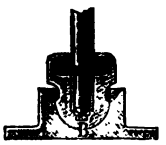
(Ground section.)
Fesca's centrifugal machine.

In Figures 15 and 16, is delineated one of the most excellent centrifugal machines both in a vertical design, and from below. The drum T is made of a $\frac{3}{4}$ centimetre (0.295 inch) thick sheet-iron plate, and is thus of a heavy weight, which is of great importance during the moment the starch milk is poured into the drum, and to cause an equal rotation of the latter.

The drum T runs independently, and is supplied with a motion from below. The drum-spindle t moves in the conical spur-bed B and in the flexible collar-bed K. The construction of the lower spherical spur-bed is delineated by Fig. 15. The lower end of the spindle has a conical groove, into which a pin of hard metal (alloy of antimony) is placed. This is the so-called spur-pin upon whose lower end the spindle rests and rotates as its bearing, which is made of the same hard alloy of antimony as is used for the spur-bed.

The friction surface of the pin and metal bearing is about 2.5 to 3.5 centimeters (.98 to 1.38 inches) in diameter, and is shaped at present entirely even, and not as was formerly the case convex upon concave or convex upon convex. Inasmuch as the entire weight of the shaft and drum concentrates on this friction surface and the velocity of revolution is great, the friction is certainly very strong, and frequently wears out, or runs the shaft obliquely. However, from two to three such metal-bearings and pins for every apparatus will do the service for each season. The entire exterior bed, having the shape of a cup, rests with its upper spherical exterior surface in the disk-shaped cavity of a second bed, the latter being fastened by screws to the foundation-plate G, and hence will yield

Fig. 17.



Lower spherical step-bearing.

at once to any pressure of the shaft, and place itself accurately in the direction which the latter may assume while in rotation.

The elastic movable star buffer-bed *K* (Figs. 15 and 16), is connected by the gum buffer-rod *m m m* with the head plate *O* of the frame, and is so constructed as to be easily movable and elastic, causing the shaft by means of its pressure, while rotating, to run obliquely in every direction. But after the pressure has ceased, it is always pushed back into its vertical, central position. In case of an unequal distribution of the contents of the drum, it is thus enabled, by dint of this elastically constructed star buffer-bed, to revolve around its own axis. On account of this elastic pliancy, Fesca's centrifugal machine insures in a high degree protection against the dangerous results of an unequal loading.

The foundation-plate *G* connected by three columns with the head-piece *O* forms the strong framework of the centrifugal machine. This foundation-plate is screwed with its four eyes *a a a a*, and small gum-washers on a wooden bed-plate; this latter, however, rests loosely on the flooring and without any connection with the same. The framework of the machine is thereby completely isolated from the flooring, and thus the shaking which it suffers by the rapid rotation of the drum is so completely taken up, that such an apparatus may be set up in any story, without fear of any shaking of the building.

The driving shaft *p*, with fast and loose pulleys *r r'*, moves in both beds *p' p''* of the frame *P*. This frame is fastened with screws to its foundation-plate *G* by four slits *b b*, in such a manner, that it may be moved upon the former, the distance of several centimetres

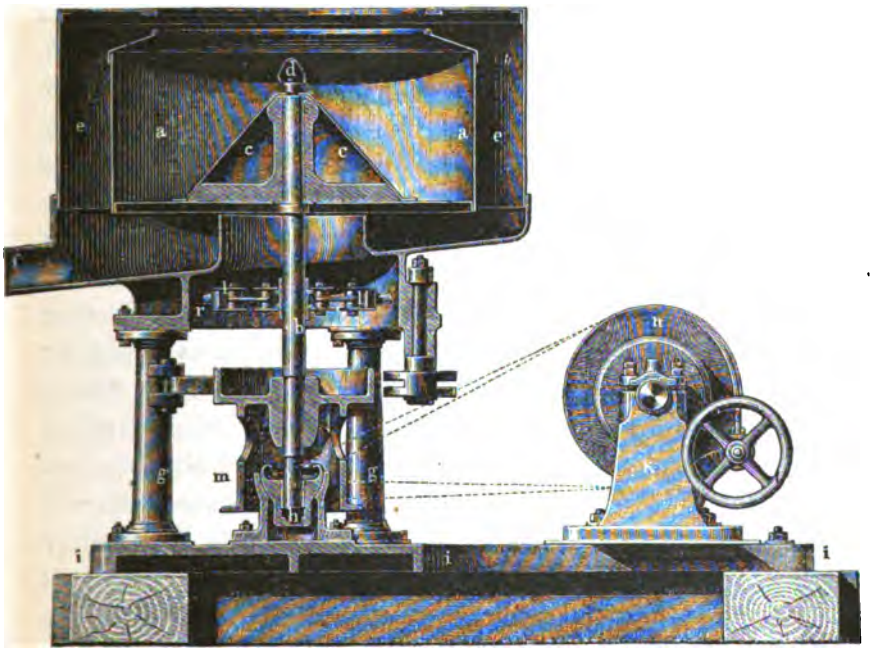
(1 cm. = .394 inch), whereby the half-crossed driving-belts L may be brought to assist the tension, in case they have by long use stretched somewhat. The belt L drives the pulley and brake-dish s; v is the handle of the double brake, which catches with two wooden blocks v' v' against the lower rim of the disk s, in order to arrest the motion of the machine after the completion of the work. The engaging and disengaging gear A is situated on the end of the "machine," and from thence several of these machines may be attended to by one and the same person. S is the mantel or shield-drum, which collects the ejected water that is flowing off by S'. The charging of the "machine" is accomplished by the so-called paste-coach, a vessel holding exactly the quantity that is needed for every drum, and which is carried over the apparatus and by means of a draw emptied into the rotating drum. The velocity of such a centrifugal machine is equal to from 1000 to 1200 revolutions per minute.

Finally, it may be mentioned, that the so-called centrifugal machine of *Seele*, as well as some other centrifugal machines of French and English construction, has its peculiar merits, but for all practical purposes that of *Fesca* as described above is preferable.

The apparatus known as "*Seele's centrifugal*" is a most excellent piece of mechanism. The drum is placed by means of a spring which catches into the corresponding notch of the shaft b of the centrifugal apparatus, and is fastened above by a female screw (nut) to the point of the cone $c\,c$. The ring affixed to this nut serves for the purpose of attaching a tackle of pulleys, by the aid of which the drum and shaft can be easily lifted out of the casing and bed.

The jacket *e e* is made of thin iron plate and fastened upon a cast-iron bottom, whose inclined plane causes the hurled-out water to flow off by *f*. This lower bottom, on which the buffer-bedding *l* is also fastened,

Fig. 18.



Centrifugal drying-machine (Seele's construction).

is borne by three iron columns *g g*, and screwed to the cast-iron ground-plates *i i*. The foundation is formed of strong oaken joists. The construction of the lower brasses as well as the buffer-beds is similar to the construction of Fesca's apparatus.

The Bleaching of Starch.—In addition to the mechanical operations requisite for purifying starch, we will now make some observations respecting the *bleaching of starch*. In many establishments for the manu-

facture of potato starch, sulphuric acid is applied, in order to impart to the starch a better appearance, although the manufacturers do not generally admit this, fearing that starch thus treated may not find consumers. There are even cases, where it becomes absolutely necessary to apply sulphuric acid for producing a white starch, as for instance in treating decayed potatoes or those affected with the "rot," or wet starch in which the fruit sap has commenced to decompose. In order not to leave in the starch any trace of latent sulphuric acid, by which it would be chemically changed (dextrine and glucose) and become thereby useless for many purposes, a small portion of ammonia should be added to the washing water. Whenever sulphuric acid has been made use of, it will also answer the purpose to neutralize the same by applying small quantities of milk of lime, in any case where ammonia should be deemed inadvisable. On the other hand, the application of fixed caustic alkalies is not expedient, since the starch combined therewith will swell up to a paste and even when used in smaller portions will become slimy, causing the process of washing to become still more difficult. Chlorides are also much used for the bleaching of starch. Thus already as early as 1821, a patent was issued in England to *M. Hall*, for extracting the yellow pigment from starch, by which the starched linen is rendered yellowish, and hence necessitating the treatment of the same with blue coloring matter (blueing). This bleaching consists in mixing the starch with water, after it has been finished to the cake formation, and afterwards diluting the starch to the thickness of cream, and adding 8 litres of the so-called "bleaching fluid" for each kilogramme (2.2 lbs.) of starch. This

bleaching fluid is composed of 70 grammes (2.45 ozs. avd.) of chloride of lime dissolved in 4 litres (8.4 pints) of water. After a thorough mixing, 8 litres (16.8 pints) of water are added, and the liquid is left to settle, in order to cause the indissoluble parts to precipitate. To this strained-off liquid 140 grammes (4.9 ozs. avd.) of sulphuric acid diluted by 8 litres (16.8 pints) of water are added and well stirred in order to cause the acid to dissolve all the heterogenous ingredients, and in the solution thus obtained 8 litres of water are poured for each kilogramme (2.2 lbs.) of starch. This fluid is then permitted to settle sufficiently, to allow the starch thus bleached and refined to precipitate. Thereupon the precipitated starch is washed out with a sufficient quantity of water to free the same from all chloride and acid, and then dried in the usual way. Starch bleached by this method is remarkably white, and all laces and textiles starched therewith attain a whiteness and lustre which common starch cannot impart.

Starch may likewise be bleached by applying the so-called "bleaching water" of *Leuchs*, which is also a solution of chloride of lime in water, to which some sulphuric acid has been added. Another means of bleaching starch, which finds much application in the manufacture of wheat starch, is the use of sal ammoniac. For the extraction of the empyreuma (fusel oil) from potato starch, of course in smaller quantities, alcohol is most profitably employed.

The Drying Process.—As the manufacture of potato starch, according to the nature of the material from which it is obtained, is generally the work for that season that intervenes between the autumn and the spring, it is necessary that heated rooms with good

ventilation, that is, with egress for damp air and ingress for dry air, be constructed. Such rooms are termed *drying chambers*. For this reason alone a steam engine is required for the needed manipulations, for instance as a motive power for the washing drum, the grater and the sifting apparatus, etc., and the exhaust steam may be utilized for heating the drying-rooms. In this drying-room frames are placed for hurdles, on which the damp starch is spread for drying. The starch, as it is obtained by the last washing from the depositing vats, or by the operation on the inclined plane, is altogether too damp to permit of an immediate transfer to the drying-room. It forms in this state a very dense dough, which usually still contains 66 per cent. of its weight of water. A part of this water must be previously removed, and this may be accomplished in various ways; for instance by repeatedly placing dry cloths over the wet and spongy mass, until these cloths cease to absorb water, or by using porous stones (bricks or gypsum slabs) as absorbents. As soon as the starch has lost its spongy appearance it is dug out with a spade and spread over the hurdles in the drying-room. The method of pressing out the water from the starch becomes only practicable when but thin layers of starch are placed under the press, because in the case of thicker layers the mass will remain wet and spongy inside. The air-pump too may be used for this purpose.

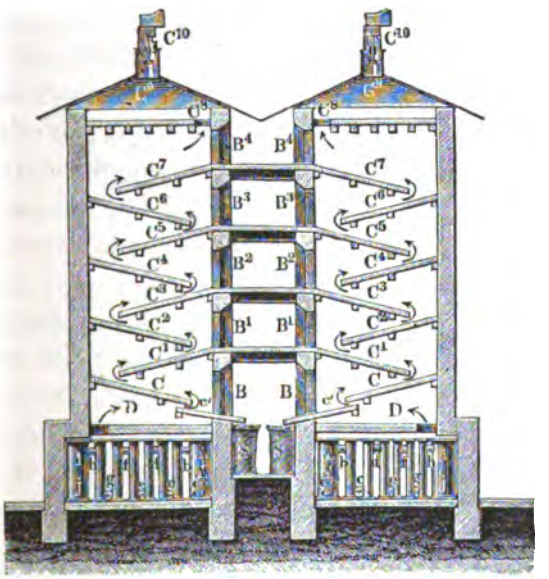
But more perfectly and expeditiously can this drying process be accomplished, by means of the centrifugal machine.

The construction of a suitable drying-room is delineated and explained as follows:—

In Fig. 19 a drying-room or starch kiln as con-

structed by Lacambre and Persac is represented. This room, on account of its convenience and ingenious arrangements, is not only used in starch manufactories, but also in breweries for the drying of malt. The drying apparatus, wherein the starch is gradually exposed to a temperature of from 25° to 100° C. (77° to 212° F.), consists of a large vaulted apartment, corresponding to the capacity of the establishment. The heating apparatus is placed below the drying-room.

Fig. 19.



Lacambre's and Persac's drying-room.

The latter consists of a large furnace *A*, which is heated by *A'* and from whence the heated articles for combustion circulate through the iron pipes *b c d e f g h i j*, and finally after having parted with the greater portion of their heat and ceased to do so, escape by *i* and *j* through the chimney. The outer air enters

through the apertures in the floors, becoming warm by being brought into contact with the heating pipes it escapes through the opening *D* into the drying-room, where it gradually passes in the direction of the darts over the inclined surfaces *C*, C^1, C^2, C^3, C^4, C^5, C^6 and C^7, finally escapes through the apertures C^8, C^9, and C^{10}, being then loaded with moisture. The starch is moved in an opposite direction. It is put in through the gate B^4 and spread on the inclined plane C^7, and after having remained there for some time is shovelled upon the table C^6, and at once drawn from the corresponding gates B^3, B^2, B^1, and *B* until it arrives below—near *C*—in a perfectly dry state, when it is finally emptied over c^1 through the gate *B*, into the bags *S*, S^1. Such a drying apparatus works continuously, so that as soon as the first part of the starch has been removed from the upper tables C^7, a fresh supply of moist starch is placed thereon. Thus, every time the dry product is withdrawn near C^1, the starch is scooped off from all the tables, viz., C^1, C^2, C^3, etc., across each inclined plane, while the uppermost table is filled with fresh starch.

The Yield of Starch from Potatoes and their Pulp.—No grating apparatus is able to open all the cells of the potato substance; hence, the entire amount of starch is never obtained by the manufacturer. The yield of starch amounts to but 66 to 75 per cent. of the starch contained in the potatoes, when the operation is performed in a rational way. The maximum yield was attained by *Fesca* with his grater and improved cylinder-sieve. 100 kilogrammes (220 lbs.) of potatoes of 19 per cent. of perfectly dry starch (= 23.17 per cent. air-dried starch) furnished him 17.5 kilogrammes (38.5 lbs.) of air-dried starch; thus 572

kilogrammes (1258 lbs.) of potatoes yielded 100 kilogrammes (220 lbs.) of air-dried starch. By carrying on this business on a larger scale, 6½ hectolitres (18.2 bushels) of potatoes (about 600 kilogrammes, or 1320 lbs.) were used for obtaining 100 kilogrammes (220 lbs. of air-dry starch, which corresponds closely enough with our statement.

The Manufacture of Potato-flour.—Potato-flour is the name given to the dried and ground potato substance after having been lixiviated in water, dried and ground, and hence is a mixture of starch and cellulose. Potato-flour when properly manufactured is entirely white, and can, with regard to its external appearance, scarcely be distinguished from potato-starch. It contains from 8 to 10 per cent. of albuminous substances,* and for this reason approaches, as to its composition, the flour obtained from cereals. At all events, potato-

* The albuminous compounds comprise a series of constituents of primary importance in histogenesis, or the formation of tissue, as the tissue of all natural forms, vegetable no less than animal, is largely composed of albumen. Albumen, the nominal, is also the actual base of this group, with which we find casein, globulin, and fibrin—these are what are called "protein compounds," a name first applied to them under a mistaken notion that they contained a certain organic base, free from sulphur and phosphorus, which was called *protein*. These compounds cannot be resolved by analysis, like complex inorganic matter, into two or more compounds that may be resynthesized into their original; and therefore no exact clue has been obtained to their very complex composition. The protein compounds are, however, extremely susceptible to the influence of the air at ordinary temperatures, decomposing spontaneously with great rapidity; this decomposition ultimately resolves them, with oxygen from the atmosphere, into water, carbonic acid, and ammonia, and various organic compounds may be formed by a less complete disintegration.

Of all the protein compounds, albumen is the special *pabulum*

flour deserves mention here as an excellent means of nutrition. This branch of industry, however, being still in its infancy, has hitherto been more especially cultivated in France, and forms a great article of export to England, where it is principally used for providing emigrant vessels with a cheap and wholesome food. Potato-flour is also used occasionally in lieu of grain flour for bread baking, for preparing soups, and as an admixture for chocolate.

The Manufacture of Wheat Starch.

The Raw Material.—The ripe grain of wheat forms a cylindrical shaped, on both ends rounded off body, which on one of its sides is deeply furrowed throughout its length. The outer cover of this body is—more especially upon one of its ends—covered with numerous fine hairs. While these hairs cling to the spurs of fungi, which come in contact with them, they cause under certain conditions injury to the grain. The specific gravity of the wheat grain ranges according to its quality from 1.32 to 1.60; the absolute weight of 100 wheat grains varies from 1.8 to 6.5 grammes (27.77 to 100 grains), which furnishes a

(nutriment) of the tissues. According to Mulder albumen is composed as follows:—

Carbon	53.5 per cent.
Oxygen	22.0 "
Hydrogen	7.0 "
Nitrogen	15.5 "
Sulphur	1.6 "
Phosphorus	0.4 "

Professor Liebig denies the presence of phosphorus as a constituent, and claims that it has no existence in any article of food, or in any tissue of the body, except in combination as phosphoric acid.

difference in the size of the grains of from 1 to 3.6. The weight of 1 hectolitre (2.8 bushels) of wheat is calculated on an average at 75 kilogrammes (165 lbs.), but varies according to its quality from 70 to 82 kilogrammes (154 to 180 lbs.). The number of the various species of wheat in a wider sense, *i. e.*, the different varieties caused by degeneration, is already very large, and yearly increased, by new methods of cultivation. Scientific men classify wheat in seven distinct varieties, but in industrial practice, wheat is classified as to its degrees of hardness, into three different kinds, to wit:—

Hard, Glassy, or *Steel-like Wheat*, with a heavy, dense, somewhat transparent, reddish grain. This wheat is least hygroscopic, rich in albumen, fat, and alkalies, and yields but little bran when ground; but the flour thereof is not very white.

Soft or *White Wheat*, with a soft, white, not transparent grain; contains less gluten, fat, and alkalies than the first kind, and can be ground with ease, furnishing a beautiful white shining flour.

Semi-hard or *Medium Soft Wheat.*—This variety holds the middle ground (as to its properties) between the first two named kinds, without possessing exactly the properties of the one or the other. It is especially valued for the manufacture of flour, on account of the ease with which it separates from the bran, and furthermore because the *grit* of this sort furnishes a beautiful white flour. The hard and soft varieties of wheat are easily discernible, by close observation of the grain, when bitten in two with the teeth or by bruising the same lightly with a hammer. Hard wheat has inside a horny and glassy appearance, like joiner's glue, having likewise its yellow color. Soft wheat, on the

other hand, has a mealy appearance, and is very tender and white inside. The former is not easily penetrated by water; the latter, however, is very easily penetrated. The physical, very sharply characterized peculiarities do not admit of an easy confounding of these two varieties of wheat. The harder kinds, as a rule, contain more gluten and less starch than the softer sorts, and are therefore more suitable for baker's use than for the manufacture of starch.

Of the soft species, there are furthermore two other groups, which the manufacturer of starch should know, *i. e.*, the red and the white wheat, which have been thus designated by their much varying color. Each of these kinds has its peculiar value for the production of starch. Inasmuch as the red wheat is generally harder, and hence contains comparatively more gluten and less starch, and besides is more expensive than the white wheat, the manufacturer of starch prefers the white and soft wheat for his use, which in every respect is best suited for producing starch.

The inner structure of the wheat-grains is best discerned by cutting one of them open and subjecting it to the magnifying power of a microscope. Such a grain is composed of three essentially different strata laying above each other, viz., the grain-shell, the gluten layer, and the flour body. The outer hull or shell is essentially composed of fibrin (cellulose or cellular substance), being indissoluble by ordinary solutions, especially so by water, and hence is in the manufacture of starch without any significance. In consequence of this indissolubility it acts in preserving the substances enveloped therein. The weight of the hull amounts usually to from 4½ to 7 per cent.; it, however, increases at times to 15 per cent. Imme-

diately adjacent to the hull is situated the gluten layer, *i. e.*, that part of the grain which contains the greatest portion of gluten. Finally we notice on the end of the grain immediately under the gluten cover, the germ, enveloped by the gluten layer. The germ is that part of the seed or grain by which the plant is developed, the *embryo.* It is impregnated by fatty oils, and when pressed upon paper causes a fatty stain. These contents of fatty oil secure to it the power to withstand the softening and destructive influences of dampness. The mealy part of the grain furnishes when ground the flour, while the shell and the germ on account of their greater toughness become less perfectly broken up and form the bran. In the mealy body two organic substances predominate: the starch and the gluten; besides these are found gum, a small quantity of albumen, and of so-called extractive substances, *i. e.*, of substances whose nature is not yet accurately known, also various salts, which are principally phosphatic.

The amount of water in the air-dried wheat grains fluctuates on an average between 11 and 16 per cent., and depends solely on the relative dampness of the atmosphere. Respecting the increase of the size of the grain by the increase of the amount of moisture, it has been found that wheat grains moistened with 15 per cent. of water increase from 30 to 31 per cent. in volume, so that for this reason to the grain dealers a high state of moisture is of greater advantage for measuring than for weighing.

The amount of starch in wheat varies from 50 to 75 per cent. of the weight of the whole.

The quantity of gluten in wheat is also very fluctuating, and as a rule is generally large, where the

contents of starch are small. In general it varies from 10 to 35 per cent. of the weight of the wheat.

The amount of gum in the grain of wheat is usually $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent.; in some cases it is as high as from 5 to 6 per cent.*

The amount of alkalies (ashy substances) varies in wheat in maximum $\frac{1}{2}$ per cent.

The amount of water (in air-dry condition) varies between 11 and 16 per cent., of which, however, on account of the drying of the wheat in a temperature of 37.5° C. (99.5° F.), but about 4 per cent. evaporates while the remainder escapes only at an increased temperature.

Respecting the chemical composition of wheat, numerous analyses have been made. The value of American wheat according to its contents of starch and gluten is as follows:—

Species of wheat from—	1000 weight parts of wheat contain—	
	Starch.	Gluten.
New York State	519.6	229.7
Pennsylvania	517.4	235.4
Virginia	486.4	260.1
Virginia	438.6	302.6
Philadelphia	448.7	329.5

As to its appearances compared with potato starch, wheat starch differs not only in form and structure, but also in this respect: that the granules of wheat starch are always smaller, hence are deposited in water much slower. For the same reason, the air-dried wheat starch is less transparent, of a dull white. In the air-dried state it contains 12 per cent. of moisture, that is, less than potato starch. For the purpose of manu-

* Its contents of albumen vary from $\frac{1}{2}$ to $1\frac{1}{2}$ per cent.—HUTTER.

facturing wheat starch it is of importance to know that a part of the starch contained in the wheat is in a very close mechanical combination with the gluten. This glutinous starch appears in every method of manufacturing starch from wheat, and occasions a loss of pure starch, since the separation of starch from the gluten is not perfectly attainable; because the "glutinous starch" is probably a compound of the unripe starch substance with gluten. From wheat-flour this gluten starch is obtained in by far larger quantities, presumably on account of the total tearing of many covers of starch-granules during the process of grinding, when the inner substance of these granules adheres firmly to the gluten. Wheat which has been affected by mildew shows in most cases such a decrease in the contents of starch, that the working up of such wheat would be unprofitable. Wheat not entirely ripe yields an inferior amount of starch. Wheat when beginning to sprout, according to the state of its germination, produces from 6 to 30 per cent. less starch than a good quality of wheat.

The Production of Starch from Wheat.—In all manufactories for the production of starch from potatoes—as we have already seen—the separation of the starch is essentially brought about in the same manner: the potatoes are grated or ground, and from the paste the starch is washed out, and only the mechanical appliances for the various operations differ. The manufacture of starch from wheat is in this respect quite different. In this the method of separating the starch is not always the same, and there are various methods of manufacturing it. The reason for this will become clear by the following: In wheat, substances are contained, besides the starch, having great value as nutri-

ments, of which we would mention the gluten. The separation of starch from wheat may be done so that a large part of the gluten may be saved as a subordinate product, but this process may also be manipulated in such a way that the greater part of this substance is lost. If the former or the latter method did not differ with regard to the ease and completeness of separating and refining the starch, the choice of the method would not be doubtful, as then only the first would be chosen. Such a difference, however, does take place, since the simultaneous gaining of the gluten complicates the complete separating and refining of the starch. Individual (local) conditions, therefore, must decide the choice, and wherever the gluten can be disposed of profitably, it will be saved; if, on the other hand, this becomes impossible, then it is allowed to be wasted. It is self-evident that the loss of a substance for food like this is always to be regretted; and it should therefore be the endeavor to perfect the manufacture of starch from wheat in such a manner as to utilize the gluten, which is obtained simultaneously during the operation. Before proceeding with the elucidation of the various methods, they should be previously characterized by a few lines.

According to the *oldest* method which is still in vogue, the wheat is swelled by water until it becomes soft, and it is then bruised. This bruised mass, diluted in water, is left to settle for several days; it ferments, becomes very acid, and of bad smell (putrefies). The tough gluten, which hinders the s paration of the starch, is partly dissolved by the acid, and partly disaggregated, and loses some of its toughness; from the fermented substance the starch can be easily and very fully separated. A modification of this method

consists in the rough grinding or bruising of the wheat, soaking the same in water, and allowing it to ferment. By this oldest method, the hulls of the wheat as well as a small portion of its gluten (at most but one quarter) are obtained in a sour state, and thus form a food only fit for hogs.

According to the second method, starch is made of the swelled and bruised wheat at once, without subjecting it to the process of fermentation, in which case sweet gluten and hulls form a residuum.

According to a third method, flour is produced from the wheat, so that bran is obtained as a valuable auxiliary product from the flour, the starch is separated, and sweet gluten also remains as a residuum.

We therefore distinguish—

A. The older method (by acidulous fermentation),
  a, from wheat not ground or bruised;
  b, from bruised wheat.

B. The more modern method (without fermentation).

C. Martin's method, consisting in the manipulation of wheat in its milled (ground) state (flour).

The oldest method is still more generally in use for the manufacture of starch, and we therefore begin with its explanation.

A. Method of Acetous Fermentation.—The fabrication of wheat starch by the process of sour (acetous) fermentation, has been carried on from a very early period, and is at present still in vogue in many establishments. In countries where the milling of flour is subject to the burden of taxation, it is the only method advisable.

This method, however, brings forth a series of in-

conveniences, as by far the greater part of the gluten, serving as nourishment for man and food for our domestic animals, is thereby lost, and the putrefied odors of the establishments endanger the health of the neighborhood, and it pollutes the streams into which the waste flows, causing a most disagreeable smell; hence, those establishments in which wheat-starch is made according to the old method, are to be counted among those injurious to health.

The manufacture of starch by this older method is divided into the following operations:—

a. The steeping and crushing (bruising) of the wheat;
b. Fermenting of the bruised wheat;
c. The separating of the starch from the fermented substance;
d. The refining of the raw starch;
e. The drying of the starch.

a. The Steeping and Bruising of the Wheat.—The steeping of the wheat in water is performed in the so-called steeping-troughs or cisterns. The purpose of this operation is, in the first place, to soften the wheat, in order to separate the starch from the gluten and the hulls; and, furthermore, to make it free from all impurities.

The steeping troughs are prepared of wood, iron, sandstone, or cement. Those made of stone are either of large sandstone slabs or of bricks, joined and cemented with mortar lime and lined with cement. These cisterns are termed "*steeping-troughs.*" The shape may be either round or square; but of more importance than the form is the suitable location of the cistern in the establishment, as it is necessary that it be easily supplied with water, and the stagnant,

already-used water as easily drained off. It should also be thought of, that the wheat to be steeped can be directly conducted into the troughs by means of a gutter, or elevator, etc. The locality where the cisterns are placed must be guarded against the freezing of the water, and hence should be supplied with a heating apparatus, in order to keep up its temperature in winter. The temperature of the locality for steeping should at least be 12°.5 to 15° C. (54°.5 to 59° F.). On the bottom of the steeping-trough is an opening, with a spigot, which is supplied inside with a sieve of copper-plate, in order to prevent the flowing off of the grain. Besides this, the bottom—near the wall—is supplied with a valve, which serves as a manhole for the suitable emptying of the cistern. Through this opening, which may also be placed on one of the sides of the trough, immediately above the bottom, the already steeped grain is despatched to undergo the further manipulation of bruising. The steeping of the wheat, which has previously been cleansed of dust and other foreign admixtures, is performed as follows: The cistern is filled to one-half of its capacity, with pure, and if possible soft water, one part of the wheat placed therein, and by the aid of wooden rakes divided, that is, diligently stirred in the water. The hulls floating on the surface, the empty grains, and dross are skimmed off with a sieve. Thereupon more wheat is put in, and the same process is repeated. After the entire quantity of wheat has been placed in the cistern, so much water is poured in as will cause it to rise to the height of from 5 to 8 centimetres (1.97 to 3.15 inches) above the wheat, and the process of removing hulls and dross is repeated. The water to be used for this operation must be pure. A pure well water is just as suitable as pure river

water, and must have a temperature of at least 10° to 12°.5 C. (50° to 54°.5 F.); but in case the steeping is to be hastened, water of a temperature of 30° to 38° C. (86° to 100°.4 F.) may be used. During the period of this steeping, some carbonic acid gas is generating, which mostly remains absorbed in the water. The steeping water assumes a yellowish color, and an odor like straw, because it partly dissolves the soluble ingredients of the hulls.

The wheat absorbs water and swells up; absorbing it to about one-half of its own weight, and the circumference of the grain grows more than one-fifth. The quantity of the extract, which the water has drawn from the hull—the color of which becomes usually somewhat paler—amounts to scarcely one-seventieth of the weight of the wheat. Gradually the wheat softens to such a degree that it may easily be crushed between the fingers when taken by both ends and thus pressed; the grains are then penetrated by the water into the very innermost part of their meal-nucleus. The time which is required for an ample steeping depends on the quality of the wheat and water, but more especially on the proper temperature of the latter. Wheat, rich in starch, of thin hulls, when not too much dried out, steeps more easily than horny, glutinous older wheat. The softer the water, and the higher its temperature and that of the locality in which the cisterns are placed, the sooner the softening process will take place. In summer four days may suffice, while during the winter season from ten to eleven days may be required.

As soon as the requisite degree of soaking has been attained, the entire steeped mass is well stirred, and the stagnant water is drawn off, and for this purpose a cock connected with a sieve plate has been affixed.

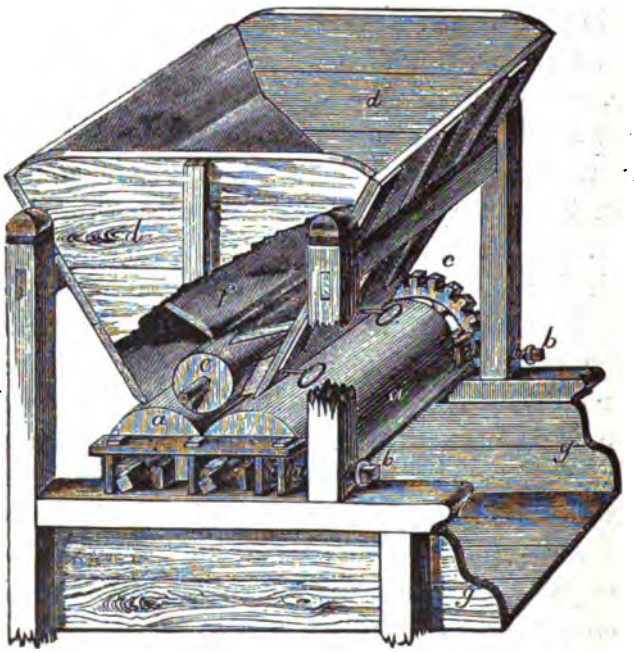
Thereupon pure water is again conducted into the steeping-trough in order to rinse off the still remaining slime. The water is then again drained out, and the grain is left to remain in the cistern several hours longer. Meantime the waste-pipe cock is left open so that the water may completely run off; whereupon the wheat is withdrawn through the manhole and taken to the crushing mill. The steeping apparatus must of course, soon after it has been emptied, be thoroughly cleaned before wheat is again placed therein. During warm weather, sometimes even in the spring and autumn, it may happen that the steeping water acquires an acid property ere yet the wheat is thoroughly steeped. This is ascertained by the peculiar acid taste of the steeping water. Water thus tainted must at once be removed from the cistern and replaced by fresh, cold water. It is best to renew the water twice or even three times during the process of steeping, and moreover this should be done oftener during the commencement of the operation than later, since the extracted substances, which most incline the water to become putrefied, are dissolved in larger quantities at the commencement of the steeping.

After the end of the steeping-process, the steeped wheat is placed upon the so-called *Bruising Mill* or *Grain-Crusher*. Such an apparatus is represented by Fig. 20.

This apparatus consists of two iron rollers *a a*, which by means of the screw *b b*, operating upon the shaft-journals, can be more or less drawn together. Both rollers are supplied on the one end of the shaft with spur-wheels, by means of which the motion, which the one roller receives by the motive power of the establishment, is transmitted to the other roller also. Above

the rollers the hopper *d* is situated, for receiving the steeped wheat. In order to place the grain very evenly between the bruising rollers, there is in the hopper a third roller of a small diameter, *e*, which on one of its

Fig. 20.



Apparatus for crushing the steeped wheat.

ends is also provided with a spur-wheel. Into this wheel fit the teeth of the wheel *c*, which is situated on one of the bruising rollers, thereby causing the turning of the thinner roller simultaneously with that of the bruising roller. By the revolving of the thinner roller the wheat in the hopper is carried away evenly from the slit formed by two inclined surfaces, which are placed above the third roller, and is thus brought between the bruising rollers. The quantity of the grain

desired to be placed between the rollers is regulated by the ledge, which is provided with a screw. The crushed substance falls into the case *g*, which is open on one of its sides. It becomes obvious that, for the process of crushing, the setting of the rollers is the most important part; the rollers must not allow one single grain to pass without being bruised, but at the same time must not crush the starch granules. In some manufactories an arrangement exists by which from the steeping cistern a conveyor (*creeper*) is conducted to the hopper of the crusher-mill for the purpose of again washing out the wheat, by letting more water run over it, while on the way.

b. The Fermenting of the bruised, ground-up Wheat.— The crushed wheat, in order to allow it to ferment, is transferred from the crushing mill to the fermenting or working tank (gyle-tun), which like all other vessels made of oak wood has, prior to its use, to be scoured out with hot water.

The large vats are filled with boiling hot water, and the smaller utensils made of oak wood are placed therein. The vats are closed by placing their wooden lids thereon, and thus filled they are left for three days to macerate. During this time the greater part of the tannic and gallic acid is sufficiently extracted by the water. After the lapse of this time, the water is drained out, and the vats, etc., again rinsed out with cold water. If this is omitted, the first starch obtained will be of a yellow color instead of being white. In the fermenting tub, the wheat substance is above all covered with the requisite quantity of water and stirred up into a thick liquidy mass. During the summer season, pure river water is used for diluting; during the winter, sour waters are added, *i. e.*, the sour liquid

which has been previously drained off from the starch. This admixture accelerates the process of fermentation. Some recommend also the use of leaven or yeast.

After the lapse of some time a scum is formed upon the contents of the fermenting tub, and a thick paste similar to the dough in the baking trough begins to rise; and it must now be observed, that, after the dough has fully risen, it is well worked up by applying wooden rakes, to cause that substance which has settled on the bottom also to rise. After the fermentation is perfected, the mass will again settle, that is, sink back to its original volume. Of course, the raking or mashing of the mass is to be repeated as often as the substance ferments and rises; and when the fermentation has ceased, it is called "*ripe.*"

The duration of the fermenting process varies greatly and depends essentially on the temperature which prevails in the fermenting room. It should not exceed 20° C. (68° F.), in which case the period of fourteen days would suffice. During the summer season this temperature can be attained more easily by a proper ventilation of the fermenting place, but during the winter season a heating apparatus is required in order to keep up the proper temperature, and to avoid having the fermentation ensue too slowly or even cease entirely. The fermentation can be accelerated in cold seasons by the application of some *sour water*, and it is usually finished, whenever the liquid appears of a yellowish tint, and is covered with an unbroken surface of fungi (usually of the species of *Pencillium glaucum*). When kneaded in the hand, it easily parts with the starch while the hulls freed of the starch remain.

The following explains the chemical process which takes place during the fermentation. When the

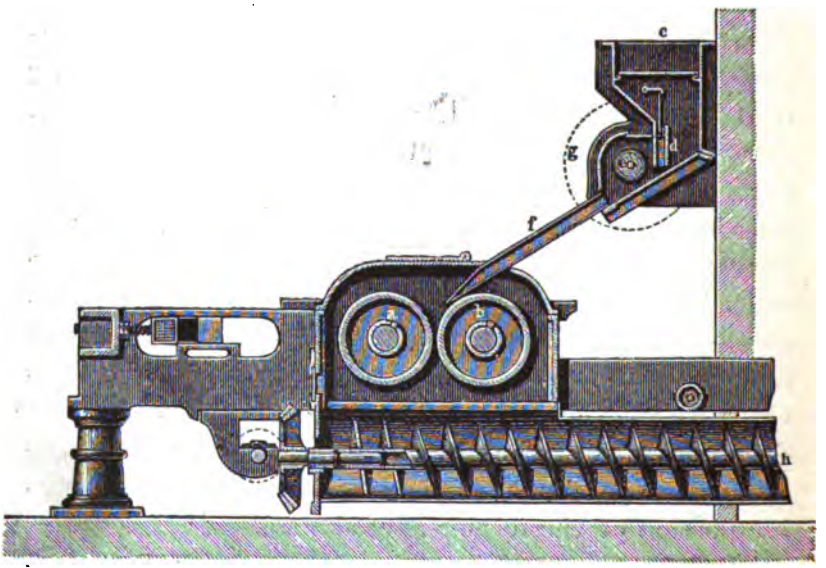
steeped and crushed wheat has been placed in the water, the latter dissolves the gum, the sugar, the albumen and diverse salts, while the hull, the germs, the starch, the gluten, and sundry other salts are not dissolved. But such a solution will gradually ferment by the admission of the air in which fungous matter is always contained, and this can be accomplished still more rapidly when sour water is added, wherein fungi already present are developed. At first the fermentation ensuing is alcoholic and hence accompanied by developing gas; this causes the rising of the substance and the forming of scum matter. Soon thereafter from the alcohol acetic acid forms, as the sour smell will indicate; then other fermentations will take place, such as lactic acid and butyric acid fermentations; and the mass becomes gradually more sour. By the acids formed, the gluten is partly dissolved, partly softened, and its composition so loosened as to be deprived of its refractory and pasty properties. In the further course of the process the putrid decomposition of the gluten begins as also that of the albumen, whereby the disaggregation of the indissoluble portion of the former is enhanced.

The effect of the acids and of the ensuing putrefaction upon the gluten is, in fact, what is intended by the process of fermentation. The starch granules are partly freed from the gluten which envelops them, and, on the other hand, the gluten is placed in a condition easily to emit the starch granules during the act of washing. But the putrid fermentation must not progress too far, because the starch granules may be affected thereby, or at least suffer in their color; the liquid too may become too slimy, if too much gluten

enters into the solution, and this will hinder the separation of the starch.

The grinding, bruising, or crushing is also performed either between the burr-stones of a flour mill, or by crushing-rollers, such as are commonly used for grinding steeped wheat, etc. Of these machines, there

Fig. 21.



Malting mill of Allsopp's construction.

are many in vogue, and of different construction; that of *Allsopp* has the merit of performing most excellent work. The general construction and arrangement of the apparatus is like that of all other malting mills. The spiral screw (screw of Archimedes) *h*, serves for the transmission of the crushed wheat to the steeping and fermentation vats. The coarsely ground wheat is mixed with the water and sour-water in the tubs, serving both for fermenting and steeping vats. Under any

circumstances, it is best, previously, to pour into these vats a few pails of water to avoid the adherence of the ground wheat upon the bottom of the vats, causing unnecessary trouble and work afterwards. After the tubs have been one-third filled with ground wheat, and the formed lumps have been stirred by the use of rakes, so much pure water must be added that it covers the grain. The mass is then carefully stirred up until it acquires the consistency of a thin paste. Thereupon, the tubs are filled up two-thirds with ground wheat, the same again stirred up, the corresponding quantity of water again poured in, and the entire mass stirred as before. Finally the last third of the vats is filled up with the grain, and again so much water added as will cover the kept-down substance. The entire mass is again stirred diligently, until it becomes so thin that the paddle may be thrust through to the bottom of the same in every direction. By this treatment an evenness of the mass is obtained, which not only furthers the ensuing of the fermentation, but—as experience proves—also favors the result generally.

After the lapse of twenty-four hours examination is made, whether the substance is much swelled. If it is noticed that the grain has risen very high but is yet too dense, more water is added, and all is again stirred. The surest test of the mass being rightly steeped consists in this, that after twenty-four hours' soaking it runs freely off the stirring paddle. The mash rising up in the centre is called "*regulus.*"

The mass is now left to ferment by leaving it undisturbed from the day of mashing—in summer from five to seven days, in the winter from ten to fourteen days—according to the higher or lower temperature.

But if the mass should rise too high, the "*regulus*" rising in the centre is gently pressed down, to prevent the air from drying it out, but without disturbing the mass itself.*

c. Separating the Starch from the Fermented Mass.—After the mass has attained the proper degree of ripeness in the fermenting-vats, the impure yellow liquid is drained off as much as possible, and thereupon the separating of the starch from the mass begins.

The drained-off acidulous liquid contains besides the gluten, acetic acid, lactic acid, butyric acid, small portions of succinic acid, salts of ammonia, some sulphate of hydrogen, and also the greater part of the mineral ingredients of the wheat, especially phosphates of clay. This substance, mixed with remnants formed in making starch, serves as swill for the food of animals or as a fertilizer, especially when the liquor has previously been neutralized by chalk.

In all the larger establishments for manufacturing starch, the separating of the same from the fermented mass is at present performed by a sieve-like perforated wooden or copper drum (washing-drum) which revolves around its axis.

Figs. 22 and 23 represent a washing-drum of recent construction.

Two spur-wheels, *a*, lined with wood between the spokes, form the side walls of the drum. The drum itself, which is from 1.1 to 1.25 metres (3.6 to 4.1 feet) long, has a diameter of 1.25 metres, consisting of a perforated copper-plate, which connects with the sides

* The advantage of grinding the wheat before steeping it consists chiefly in avoiding the time absorbing soaking of the whole grain.—HUTTER.

Fig. 22.

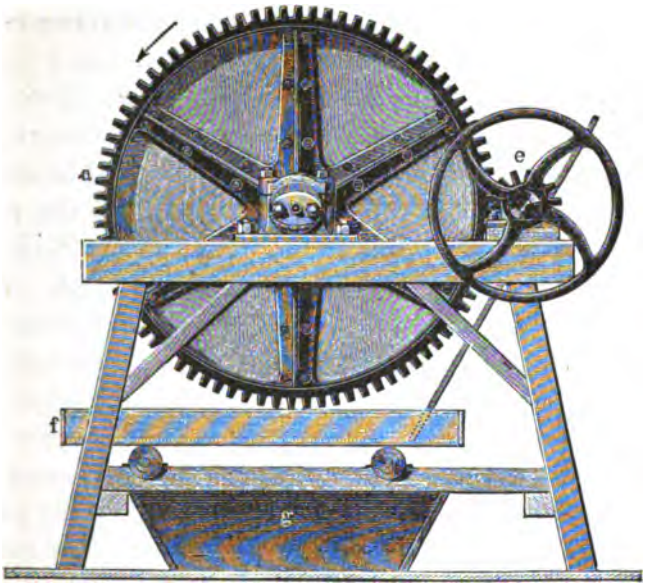
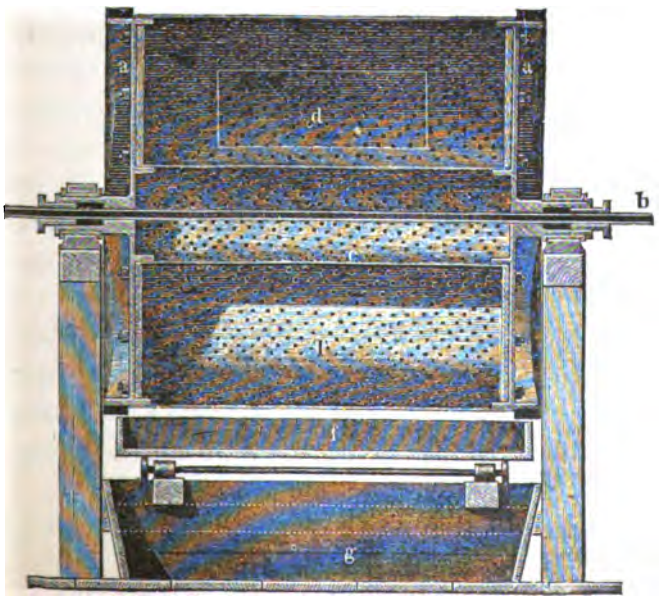


Diagram of Washing Drum of recent construction for separating starch from the mash.

Fig. 23.



Longitudinal view of same.

by being riveted to the cast rims of the same. Through the shaft of the drum, *i. e.*, the stuffing boxes in the shaft beds of the sides, passes the water pipe *b*, which is also perforated, inside of the drum. This pipe is likewise covered in the drum by a perforated pipe *c*, of 24 to 32 centimetres (9.45 to 12.6 inches) in diameter, whereby the stopping (clogging up) of the openings of the water-pipe is prevented. For filling and emptying the drum the gate marked *d* is used.

After the drum has been filled with the fermented mass of from 6 to 12 hectolitres (16.8 to 33.6 bushels) of wheat, water is conducted into the water-pipe, and the drum, by means of the pulley *e*, makes a slow revolution in the direction of the dart. The raw-starch milk flows from the drum into the box *f*, which is put underneath the drum, this box running upon rollers. From thence the starch-milk flows through a spout in the depositing vat. After the lapse of from three-quarters of an hour to an hour and a quarter the mass is completely washed out. The box is withdrawn from under the drum, the door of the drum opened, and turned so that the opening is below, and the residue is allowed to fall into the funnel *g*, which carries it to the place of storage.

This residue is a mixture of hulls, a part of the mostly uninjured oily germs, and the adhering softened and sour gluten. It serves as food for hogs, and may also be applied for the mixing of the sour-water.

The raw-starch milk contains the starch, glutinous starch, finely divided sour gluten, and finely divided hulls, augmented by such substances of the wheat, as have been dissolved by the acids, created during the fermentation.

A more complicated apparatus for separating the

starch from the fermented substance, is the so-called treading-mill, which is still used in some establishments.

d. The Refining of the Raw Starch.—The starch-milk flowing from the wash-drum contains, as has been stated, besides the starch also glutinous starch, finely separated sour-gluten, and the finely divided hulls of the wheat, impregnated with substances which were brought into solution by formed acetic, lactic, and other sour agents during fermentation. This starch-milk is now directly conducted to the deposit vat. Generally there are two such vats in every establishment, each of them having a capacity of about 20 hectolitres (56 bushels) of wheat. In the vats a stirring appliance is affixed which can be brought into connection with the motive power of the manufactory. This stirring apparatus can be raised and lowered at will. The stirrer used for the manufacture of potato starch is for this purpose likewise suitable.

When a deposit vat has been filled—in case the starch-milk is not thin enough more water is added—the stirring apparatus is set in motion in order to completely stir up and mix the contents of the vat. After the raising of the stirrer, the starch-milk is left to settle for a period of about four days. After this period the suspended substances, that is, the starch, the glutinous starch, the sour disaggregated gluten, and the hull fragments have settled to the bottom. Since, however, the specifically heavier starch granules are deposited much faster than the glutinous starch, the gluten and the hulls, therefore the heavier starch occupies the lower part of the layer which rests on the bottom of the tank; above it rests the glutinous starch; on the top is found a slimy liquid layer, composed of yel-

lowish, sour gluten and fine portions of hulls. A sharp division of these layers does not take place, but a gradual transition from one layer to the other occurs. The liquid standing above the deposit in the vat is gradually drained off through the bungholes until the slimy portion of the deposit is reached. This slimy layer is then also withdrawn—but in a separate vessel—in order to gain the starch contained therein. After the closing of all the bungholes, pure, clear water—best well water—is poured into the deposit vat, the sediment again thoroughly stirred up, and the starch-milk, run through a fine hair-sieve, is divided into other depositing tubs. This sifting is done for the purpose of completely removing remaining impurities—particularly the finely divided hulls—and is carried out in the following manner: the white starch deposited in the vats is gradually loosened to the bottom, by means of the so-called "*bleak*" or "*blay*"—a two-edged 10 to 11 centimetre (3.94 to 4.33 inches) broad knife of the shape of a spade—so that the entire sediment is cut into small pieces, and nothing thereof sticks to the vat. The starch-mass is thereby enabled completely to receive the water poured thereon, and to mix therewith easily. The fresh water is poured about 48 centimetres (1.57 feet) high above the starch-mass, and stirred well, either with the rake or the stirring apparatus, until the whole is a uniform liquid, and no more solid pieces adhere to the bottom, whereupon the vessels are filled up entirely with pure water, and all is again well stirred. The white starch-milk is then strained through the hair sieve into one or several well-rinsed depositing vats or washing-tubs. The sieve is placed for this purpose on two round (smooth and

clean) poles which are placed at a proper distance parallel and above the depositing-tub, and as often as the same has been filled with starch milk, to be shaken on these poles to and fro. If the sieve gets clogged up in consequence of the hulls or bran depositing on the bottom of the same, some pure water is poured thereon, and it is permitted to run into the depositing vats. Thereupon the sieve is put upside down, and some more fresh water is poured on the lower side of the same. By this simple operation all foreign ingredients can be removed with ease, and the starch-milk can again pass through the sieve without hindrance. Should the starch substance in the depositing vats have become somewhat too thick in the lower part of the tank in consequence of the starch having again somewhat settled during the previous work, more water should be added, and well stirred up. The strained starch-milk must also be occasionally stirred in order to separate the small hull particles which have pressed through the sieve, and other bodies, not belonging to the starch-mass, which float on the surface, as well as any acidulous matter which may yet adhere to the starch. If this operation is not conducted with great care it may easily occur that the starch produced will be full of holes, poor looking, and as a consequence not be desirable in commerce. The same might also happen in case the starch is left too long in the depositing vats.

It is also recommended to effect the straining of the starch under water, whereby the yield of starch can be greatly increased. If a sieve is used with such narrow meshes that it is impossible for the starch granules to pass through, they will deposit themselves on the sieve

bottom, and the process of straining will take place only in drops; hence this process of straining on a larger scale is inadmissible. But if, on the other hand, the sieve containing the starch, which is to be refined, is placed under water, instead of pouring the starch containing water upon the cloth, the water impregnated with the starch-granules will be raised and flow to the surface, and force the starch along, leaving the foreign substances to settle on the bottom of the sieve. This will be easily accomplished by turning and shaking the sieve during the operation.

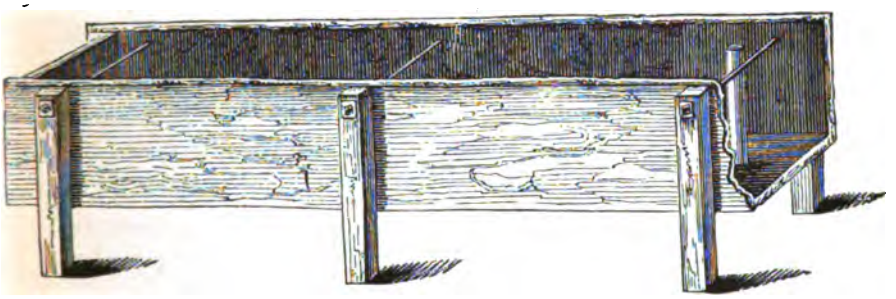
The apparatus serving for this purpose consists of, 1, a wooden tank; 2, of a second wooden vessel or box of somewhat smaller dimensions, fitting accurately inside of the first tank, its bottom composed of silk gauze; 3, of an undershot paddle-wheel, whose shaft rests upon two bearers, being fastened on the rim of the larger tank. By the mechanism of this wheel the sieve can be given a shaking motion, or an alternate motion up and down. The impure starch is admitted through a gum hose into the sieve, while the water impregnated with the starch, that has passed through the sieve, flows off through another siphon-shaped pipe.

The depositing-troughs, made of pine wood, are about 1 metre high, and 0.8 to 1 metre (2.62 to 3.28 feet) wide, tapering off somewhat conically towards the bottom. They are also supplied with bung-holes, at different heights, for the draining off of the water. The shape of these depositing-troughs is delineated in Fig. 24. They are about 64 centimetres (2.1 feet) in width, and are at present more commonly used than the tubs.

The aim should be to divide the starch milk very

evenly in the smaller vessels, and if necessary it should be diluted with fresh, cold well water, and well stirred

Fig. 24.



Depositing-trough for refining wheat starch.

so as to obtain an equal mixture. In these small depositing vats, the starch milk remains until a complete deposit of the suspended substance is effected. This occurs within three days. Then the liquid standing over the residuum is carefully drained off, and if necessary the upper portion is also removed by a careful edulcoration (washing), until the pure starch appears. This operation may be facilitated by the aid of a moistened feather-wing. The edulcorated mass is placed in separate basins (receivers), for further operations.

A repeated edulcoration of the starch is usually not resorted to, although it is self-evident, that by so doing, a greater purity of the product is attained. Too frequent edulcoration, however, is avoided for the simple reason that starch so treated thereby loses the property of forming a cohesive substance when dried, a qualification imperatively demanded in commerce. As soon as the deposited starch no longer colors blue litmus paper red when pressed thereon, it proves itself free from acid and also free from soluble substances generally.

Far more expeditiously and completely than by stirring, depositing, settling off, etc., or by channelling, can the process of refining be attained by the use of a centrifugal machine, which, in order to distinguish it from the other starch-refining apparatus, is by its inventor termed—

The Raw-Starch Centrifugal Machine.—This apparatus differs from the usual machines of this kind by its drum not being a sieve-drum, and hence no liquid will be hurled out of it. If gluten-starch, etc., or rather impure starch-milk is admitted into the revolving centrifugue, the same process occurs as has been explained in the operation of a similar apparatus for rectifying potato-starch. The suspended substances of the starch milk deposit themselves on the sides of the drum, rotating according to their density and respective specific gravity. In the *outer* line the starch is deposited, then the dressing and the gluten, and as the liquid (the water), as has already been stated, is not hurled out, but being of the least density and also of the least specific gravity, it forms the innermost stratum in the apparatus. After the drum is brought to a stand still, the liquid of course runs to the bottom of the drum, and can by means of an opening, which can be closed during the working of the machine, flow off. This having been attended to, the impure layer of the gluten and dressing can be removed from the drum. The *gluten-starch*, thus separated, forms a yellowish-gray paste which, when ground, furnishes a flour containing from 5 to 6 per cent. gluten.

For practical purposes it would be best not to apply at once the centrifugal apparatus in operating the raw-starch milk as soon as it is taken from the wash-

ing drum, but to allow it, after stirring, first to settle for several days, then to draw off the liquid in order carefully to remove the upper (slimy) layer, then to stir up the raw-starch in water and finally apply the raw-starch centrifugal machine. By means of this apparatus, the operation is performed in a few hours, which by the older method of stirring, precipitating, and by inclining gutters, can only be effected in as many days and moreover not so efficaciously. By application of the centrifugal apparatus for refining starch, the last process of purifying the same is effected.

e. The Process of Drying.—While potato-starch cannot well be manufactured during the summer season with profit, on account of the scarcity of the raw material, the manufacture of wheat-starch is with some chiefly the work of that warmer season.

What has been said with regard to the drying of potato-starch, is also generally applicable in the drying of wheat starch. Let us suppose the starch has been cleaned in the depositing tubs or vats, and left therein to be "dug out." To prepare it for this, some of the water which it yet holds absorbed, and still contains, must first be extracted. This was formerly effected (and in smaller establishments is even to this day) by covering it with some clean cloths which are often changed and wrung out. This operation is finished whenever the starch-cake no longer appears spongy in the centre, but solid. If some dry starch is thrown on these cloths (so as to cover them several inches), it will absorb the moisture eagerly, and the starch may be dug out after the lapse of but a few hours. This digging is performed with an instrument like a spatu-

la, or with a long knife with a narrow back. The starch mass in the tub is cut twice (crosswise) down to the bottom. This manipulation furnishes four pieces in every tub, which must be lifted out gently and carefully. The withdrawing of the first piece is made easier by inserting into one of the cuts a hard, thin piece of board of about 32 centimetres (12.6 inches) in length; and after loosening the other pieces carefully all around with the knife, firmly taking hold of the piece, at the same time grasping as deeply as possible into the cut, lifting the starch on the board designed for carrying it away, and in such a manner that the starch is neither broken nor pulled. The other pieces can then be removed with greater facility. But by inserting the board into the cut the same must be moved gently to and fro, in order to loosen the starch on all its sides without tearing it asunder. But far more simple and easy is the digging out of the starch from the depositing chests. Pieces about 32 centimetres (12.6 inches) square are formed therein, that is, of one-half the size of the width of the chest. This circumstance explains sufficiently the reason why these depositing chests are preferable to the tubs, independent even of the more convenient shape which the starch-cakes thus obtain. The pieces dug out are placed in the drying-room and weighed down with bricks. In the course of about twenty-four hours, these bricks absorb a great quantity of moisture from the starch-cake. Instead of bricks, slabs of gypsum may be used, and also upon such slabs the starch pieces may be laid.

In larger establishments, and especially in those of a more recent construction, the preparatory drying of

the starch mass is generally no longer performed by applying cloths, bricks, and gypsum slabs, but by means of air-pumps. The starch is then brought into the drying-room, where at a temperature gradually approaching 60° C. (140° F.) the last remains of moisture are taken off. In order to be convinced of the perfect dryness of the starch, a piece is broken in two, and the break is scraped with the nail of the thumb. If a gnashing or crackling sound is observed, and, moreover, if upon the angular side of the fracture longitudinal stripes are seen running together, such are to be considered as a sign of an excellent starch, and the starch is then finished to perfection.

B. Methods without Fermentation.—The reason for endeavoring to substitute for the manufacture of wheat-starch by fermentation another method by which the process of fermenting is avoided, has already been stated. By fermentation, the greater part of the nutritious substance of the wheat is destroyed and run off, so especially the gluten, an ingredient contained therein in abundance. Such a loss of useful substances, considered from an economical point of view, is truly deplorable. But we feel that the general introduction of the manufacture of starch from wheat without fermentation is impeded or rendered difficult, as otherwise the process of fermentation would have been abandoned long ago. What can this obstruction be? Although by the method of fermenting, the starch is being furnished in the easiest and most perfect manner, yet by the methods without fermentation the gluten is obtained in such a condition as not to be at once fit for food. Although gluten possesses a great value as a nourishing protein substance, when it is intermixed with starch, as in flour, but just so little

is it suitable as an article of food in its crude state, as is proven in the manufacture of starch without fermentation. It must previously be deprived of its sticky, glutinous condition, or by mixing it with suitable substances must be divided. In all methods of manufacturing wheat-starch without fermentation there must at the same time be considered the suitable utilization of the gluten, and only where this is accomplished are those methods profitable. Every judicious proposition for using the gluten to advantage, is a further step in the development of manufacturing starch without the process of fermentation, and every improvement in this process for increasing the yield of starch furthers the propagation of that method. There are two different methods of making wheat-starch without the process of fermentation, and moreover to also obtain the gluten, *i. e.*, the method of working the whole grain, and the method of operating the ground wheat (flour).

The Manufacture of Wheat into Starch, without grinding the Wheat.

This method is essentially the same as has been mentioned for the testing of the wheat, with regard to its yield of starch generally. It begins with the same operations, by which the fermentation process commences, namely with the steeping and crushing of the wheat. The well-cleaned wheat is saturated with water and left to macerate until the grains can be easily pressed between the finger ends, and thereby give a milky juice. During the warmer season, the steeping water must be frequently renewed, to prevent it from becoming sour and of bad smell. It is very proper to apply tepid water, for hastening the steeping

process, since if wheat remains too long in the water, the gluten softens, becomes smeary, and furthermore during the manipulation of washing out, part of it is washed away.

The wheat amply steeped and freed from the adhering water by draining, is bruised between rollers of stone or metal, and this bruised mass is best again crushed between rollers, after having previously been pressed out. From this pasty mass the starch is then separated by washing, or to say it plainer, the starch is separated from the gluten and the hulls. That this operation does not take take place as fast and as easy, as is the case when the sticky gluten that envelops the starch is previously dissolved or disaggregated, is obvious. In so-called filter-bags the operation succeeds well enough, but it is unhealthy and expensive. The process of washing out in the drum, being also recommended, can hardly result more favorably, inasmuch as lumps must form from which the starch cannot be washed out by the water which is flowing upon them.

Fesca has constructed a washing-apparatus which fulfils perfectly all the objects in view. The raw-starch milk is allowed to settle for from 20 to 24 hours, and after drawing off the very slightly sour liquid, the raw-starch paste which has deposited in the vat is worked in the raw-starch centrifugal apparatus. Here it is separated into raw-starch and gluten-starch, which latter is obtained in the form of a yellowish-brown paste, and furnishes, when dried and ground, a flour containing from 5 to 6 per cent. gluten. The raw-starch is subjected to a fermentation for several days. This is accomplished by placing the same in small vats, and in order to dissolve the

residuum of gluten, it is finally washed and finished in the "refining centrifugal apparatus." By this method a greater yield of starch is obtained than by the common process of fermenting, and one equally as large as when the latter process has been supported or aided by the use of the raw-starch centrifugal machine.

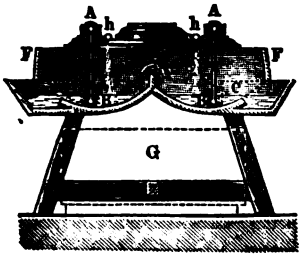
The Manufacture of Wheat Flour into Starch.

The obtaining of wheat-starch and gluten from the ground wheat or flour, is a method introduced by *E. Martin*, which, besides rendering a larger yield of starch offers also, on account of perfectly utilizing all the residues for food, yet far greater advantages than all the methods thus far explained, so that the fact that this is not yet generally heeded seems remarkable. This method should have long since crowded out all other modes of operation for producing starch, and should be exclusively used. Of course the expense of reducing the wheat into flour, attending this method, is also to be considered, while, on the other hand, the value of the bran resulting from the grinding, as also the obtaining of sweet gluten in separating the starch, must be deducted from such expense.

By Martin's method, the flour is kneaded—in the proportion of 100 to 40 of water—into a stiff dough, either by hand or by a kneading-machine. After the dough has laid for one or two hours, it is manipulated in parts in a fine sieve, under a continual flow of a jet of water, until the water ceases to flow off milky, when the gluten remains as a gummous tough mass. The manual labor in this case, as well as in that of the kneading, is very troublesome and slow, and therefore very expen-

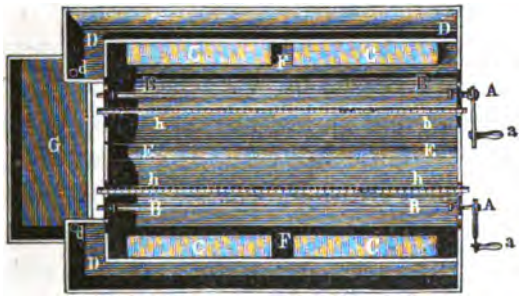
sive, and has consequently been supplanted by the application of machinery.

Fig. 25.



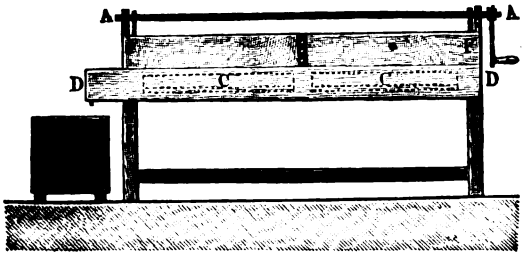
(Vertical diagram.)

Fig. 26



(Upper view.)

Fig. 27.



(Vertical longitudinal section.)

1 Metre.

Figs. 25, 26, and 27.—Washing apparatus of recent construction, for extracting the starch from the wheat flour according to Martin's method.

The main principle of the different kinds of machinery which serve for this purpose is always the same, and is so arranged as to roll thick string-like noodles, formed from the dough, under a gentle pressure to and fro upon the surface of a sieve, of course while water is kept constantly flowing over them. These noodles are from time to time turned over, to change their surface. Such a washing apparatus of recent construction is delineated in Figs. 25, 26, and 27. *F F* (Figs. 25, 26, and 27), wooden troughs of 2 metres (6.56 feet) in length and 1.5 metres (4.92 feet) in width. By Fig. 25 it becomes plain in what manner one part of the periphery of the troughs is cut out, and in lieu thereof is covered with the wire-cloth *C C*, which is drawn over wooden frames. Alongside of the troughs are wide gutters *D D*, which, by a movable apparatus for the flowing off of the water, regulate the level of the liquid, so that it reaches in the gutter and trough, up to half of the height of the wire-cloth, while all the other starch containing water flows off, through the higher or lower placed pipe *d* (Fig. 27), into the collection vat *G*.

Above the common partition of both troughs near *E* (Figs. 25 and 26), a bent piece of tin is fastened, which serves to bring back the waves of the moved liquid, so as to prevent an overflowing from one trough into the other. *A A* are two iron shafts resting upon beds which are fastened on the rims of the troughs. Each of them has on its end an iron (fork-shaped) extension, and on these are fastened the ends of the grooved wooden rollers *B B*, so that the latter can revolve freely in them. The shafts *A A* receive through the cranks *a a* half a turn, alternately towards the one or the other direction, whereby the rollers *B B* are moved to and

fro across the bottom of the troughs. At the beginning of the operation the turning of the cranks requires a considerable effort. After working for about ten minutes, however, the volume of the dough has been greatly diminished, whereby the labor becomes essentially easier. The water is conducted into both the troughs by means of copper pipes perforated with fine holes (roses), which during the entire operation squirt thin streams of water upon the dough which is kept moving underneath. For the kneading of the flour, a kneading machine moved by steam power is used, by which within from 10 to 12 minutes from 400 to 500 kilogrammes (880 to 1100 lbs.) of dough can be prepared.

The dough having macerated from one to two hours, and the gluten having absorbed sufficient moisture, it is then worked up into pieces of about 1 kilogramme (2.2 lbs.) in size, and equal portions placed in the troughs. The next operation consists in the moving to and fro of the rollers. The man attending has to observe that the wire sieves do not become stopped up with gluten, and if this should be the case to clean the same by means of brushes. Besides, in case the dough balls up into larger lumps, the attendant must at once divide the same.

The washing out of the dough—which lies partly under water—takes usually one hour, and will be under all circumstances entirely finished whenever the water flowing off no longer carries along any particle of starch. The waste-pipe *d* (Fig. 26) is then entirely withdrawn from the gutter *D*, whereby the liquid contents of the gutter and trough flow off into the reservoir *G*.

The gluten remaining in the trough is freed of its surplus water by five minutes constant kneading, then

removed from the trough for further manipulation, and the apparatus used for another operation. *J. B. Polaillon*, and *F. Maillard*, of Lyons, recommend for producing starch from wheat flour the following method, without kneading: The wheat is milled, the flour freed of the bran, mixed with an ample quantity of water, and the mixture left to macerate for some time—according to the quality of the flour—but the decomposing of the gluten must be avoided. The pasty mass is worked through a fine wire-sieve, upon which simultaneously water is flowing from a rose. The passing of the mass through the sieve is accelerated by an apparatus which, while rotating, presses on the same. From the wire sieve the mass flows over long gutters (inclined planes), and the starch deposited therein is washed in the manner already described.

Guided by the previous process, *Fesca* has recently described a new method for manufacturing starch by simply applying the centrifugal apparatus, without the kneading of the dough. According to this treatment, the wheat flour is mixed with water into a thin paste, and worked in the *raw starch centrifugal machine*, where the raw starch becomes immediately separated from the gluten paste. The raw starch contains almost the entire free starch, a little bran, and a small portion of the insoluble gluten; the gluten paste contains the greater part of the insoluble gluten, part of the gluten starch, some raw starch, most of the bran and nearly all the soluble ingredients of the wheat flour. The raw starch is then in the usual way further manipulated, stirred up with water, allowed to ferment, and is refined.

This method of producing starch is in a national economical respect of the highest importance, and espe-

cially since the loss of valuable substances thereby is but very insignificant, and is almost exclusively confined to those substances which are taken off by the edulcorating (wasting) water from the raw starch. The gluten-paste contains the larger quantity of substances which, besides starch, are found in wheat. In every respect *Fesca's* latest method excels all others, as with them, the soluble ingredients of the wheat (albumen, gum, and salt) are almost entirely lost, while a part of the soluble substance of the gluten is also lost.

For the pursuit of this method of fabrication, the most suitable species of grain are the semi-hard or medium soft kinds of wheat. Neither from the hard nor glassy (flint-like), nor from the soft or very mealy wheat species can the production of starch be effected with equal success.

Producing of Starch on a small Scale for Domestic Use.

In farmers' families, they frequently make the starch needed for home use themselves. The simplest method is the following:—

Take one hectolitre (2.8 bushels) of good wheat, which has been freed of all impurities, place the same in a vessel of corresponding size, and pour as much water thereon as will cover it completely. After the lapse of twenty-four hours, the wheat is well stirred, the water, after having settled again, is drained off and replaced by fresh water. After the lapse of another twenty-four hours this water is also withdrawn, and this operation of changing the water is continued until the substance in the wheat can be pressed

out in the form of a thick milk. Thereupon this milk is pressed through a linen bag into a clean vessel. This first product is separately preserved, as it furnishes the finest and purest starch. The residue remaining in the linen bag is mixed with water and again strained; the starch gained from this residue is of course of an inferior quality.

The first product is given twenty-four hours to settle, the water above the same is drained off and supplied by fresh water, and the starch mass stirred up, repeating this after the lapse of twenty-four hours. As soon as the water appears entirely clear and pure, above the starch mass, a clean cloth is drawn over a frame, and by means of a ladle, the starch—after withdrawing the water—is taken out and left to dry in the open air.

Another still shorter method consists in placing a suitable quantity of fine wheat flour in a bag of fine linen, tying the same well, and kneading it beneath a stream of water, which is allowed to flow upon it, by which operation the water will carry off the starch, while the greater part of the gluten remains in the bag. The water thus impregnated with starch is filtered through a silken sieve, and then manipulated as described above. The first water used in kneading out the starch can, after having deposited all the starch, by means of fermentation, be utilized for making a pleasant beverage, tasting like weiss-beer.

Special Methods for Refining and Bleaching of Wheat Starch.—Considering the fact that the wheat starch always retains greater or smaller quantities of gluten, which adhere mechanically to it, but the removal of which, at times, occasions to the manufacturer great

difficulties, the most various methods for refining and bleaching have been proposed. Some of them we will here describe.

E. Nash applies for the removing of gluten from the wheat starch, ammonia, as experience has convinced him that liquid ammonia is the best means of dissolving the gluten, also the pigment, and all soluble impurities of the starch in as far as it exerts a powerful action on the gluten and the pigment without affecting the starch. Liquid ammonia of 0.945 is of sufficient strength, and is preferable to caustic-soda or caustic-potash, since the saturated solutions of the same affect with equal force the starch and the gluten. The application of ammonia has also the advantage of extracting from the starch the astringent substances.

Ammonia can be used for refining the starch in the liquid (ammonia water), or also in gaseous form. In the latter case it is permitted to enter the vessels containing the starch by means of refrigerators. For this purpose closed vessels are most suitable; and for accelerating the process the temperature of the mass may be increased without fear of thereby affecting the starch. In most cases, however, an application of ammonia will suffice to cover all practical purposes without heating the starch. Based on the experience of *Nash*, ammonia can be recommended with great advantage for conserving and improving all flour-containing substances. So, for instance, all inferior sorts of rice, beans, and peas will gain materially in quality and taste, when they are, previous to cooking, steeped in ammonia-water, and thereby freed of their impurities. Nash recommends, under all circumstances, to add to the starch, prior to finishing the same, some ammonia.

Samuel Hall recommends for extracting the yellowish pigment, the application of chloride of lime, which is diluted with water to such a degree that in 100 litres (26.4 galls.) water 1½ kg. (3.3 lbs.) chloride of lime are dissolved. The starch is now, after having been finished to the forming of cakes again, stirred up in water and diluted to the thickness of cream, thereupon for each kilogramme (2.2 lbs.) of starch 9 litres (2.38 galls.) of bleaching liquid are added. After all has been well stirred 20 litres (5.28 galls.) more water are added, and then the mixture is left to settle, so that the insoluble parts may precipitate to the bottom. In this drained-off liquor are now poured 133 grammes (4.66 ozs. avoirdupois) of sulphuric acid, diluted in 9 litres (2.38 galls.) of water for each kilogramme (2.2 lbs.) of starch; after which the same liquid is again poured over the starch in order to cause the acid to dissolve all foreign substances, and into this solution finally 18 litres (4.75 galls.) more water are poured for each kilogramme of starch. The liquid is then permitted to rest a sufficient time in order to allow the refined and bleached starch to settle to the bottom. The precipitated starch is thereupon freed, by the use of a great deal of water, from all chloride and sulphate of lime and free acid, is formed in cakes in the above described manner and afterwards dried.

Starch treated thus is very pure and of great whiteness, laces, cotton textiles, etc., starched therewith obtain a whiteness and gloss which they would never acquire by the use of common starch.

E. Tucker purifies his starch with a weak solution of glauber salts. The proportion is for a quantity of starch obtained from 1000 kg. (2200 lbs.), of wheat, 6 kg. (13.2 lbs.) glauber salts (sulphate of soda).

According to *Martin's* method, the impure starch can be freed of foreign admixtures and a better quality obtained by washing the same, not only with water, but also by adding to it some caustic soda. To this end, the first product gathered upon the inclined plane is mixed with water and a solution of caustic soda of 2° B. added thereto until reddened litmus paper turns blue therein. In most cases a two hours' maceration will be ample, and the starch be freed from foreign ingredients. After the effect is plainly visible, this solution is diluted with a large quantity of water, permitted to pass through a very fine hair-sieve, whereby swelled-up gluten and other foreign bodies remain in the sieve, while the starch flows through. After a brief interval, during which time generally small portions of sand deposit themselves, the starch-milk is permitted to run over inclined planes, and in this manner a much larger yield of pure starch results, than by the common method of washing.

Kirchhoff recommends for refining gluten containing wheat-starch the following operation: Take three parts of potash and four parts freshly slaked lime to one hundred parts of water, and a caustic solution is thus prepared, of which for each one kilogramme (2.2 lbs.) of the starch one kilogramme of the solution is taken. The whole is frequently stirred and left to settle for two or three days in a medium temperature. Thereupon, the starch is diligently washed in order to free it of the adhering lye.

Leuchs proposes for the removal of gluten from wheat-starch in lieu of the fermenting process, the extracting (washing out) with kali- or natron-lye, which then, for the purpose of bleaching, is to be saturated to one-sixth to one-fourth with chlorine.

The Manufacture of Corn-starch (Maize-Starch).

Maize or Indian corn (*Zea mays*) is a native plant of North America, but is at present cultivated in all warm climates, and is even in lands of a colder climate largely planted. The varieties of maize are very numerous, exhibiting every grade of size, color, and shape, between the shrubby reed that grows on the shores of Lake Superior to the gigantic stalk of the Ohio valley; the tiny ears with flat, close, clinging grains, of Canada; the brilliant rounded little pearl, or the bright red grains and white cob of the eight rowed hæmetic, to the swelling ears of the large white and yellow seed of the South. There are something like eleven principal varieties cultivated in the United States, which may be distinguished by the number of rows of grains on the cob, and the color, shape, or size of the kernels.

Wherever maize is cultivated in large quantities, it is not only used for distilling high wines, but principally for producing starch, and as food for man and beast. As is the case with wheat, so also maize varies as to the composition of its grains, according to climate and soil. In general, it may be asserted, that the contents of starch in maize fluctuate between 50 and 60 per cent., as the result of the following analyses will show:—

	Composition of 100 weight parts maize according to		Maize flour (corn meal) according to
	R. Fresenius.	Poggiale.	Stepf.
Water	13.46	13.5	10.60
Fat	5.11	6.7	3.80
Gum (dextrine)	2.33	....	3.05
Sugar	....	....	3.71
Albumen	....	....	0.61
Protein generally	10.04	9.9	6.71
Starch	65.90	64.5	71.52
Fibrin	1.58	4.0	....
Ashy ingredients	1.58	1.4	....
	100.00	100.0	100.00

From the following Table the composition of the various species of corn can be learned.

Percentage composition.	American maize.		
	Flat white.	Flat yellow.	Round yellow.
Water	11.8	11.5	13.2
Starch	54.8	53.5	54.8
Cellulose	15.9	16.5	14.9
Starch, cellulose, and loss	....	....	....
Gum	....	....	....
Sugar	....	....	....
Gum and sugar	2.9	2.3	2.9
Fat	4.4	4.7	4.4
Extractive substances	....	....	....
Pigment	....	....	....
Albumen	....	....	....
Soluble albuminates	....	....	....
Insoluble albuminates	....	....	....
Gluten	8.9	8.7	8.9
Ashes	1.8	1.6	1.8
	100.5	98.8	100.9

Respecting its anatomical structure and its qualitative chemical condition maize is very similar to wheat; from this it follows that the method of separating the starch from the maize does not essentially differ from that used with wheat. But inasmuch as the gluten of the maize does not form such a tough mass as the wheat gluten, it is not necessary to soften and dissolve

it by fermentation, but the fermenting process is omitted, and hence we can always obtain the gluten as an excellent food for domestic animals.

The first experiments in making corn-starch were made in America and England. The Indian corn (maize) is, after a previous cleaning of adhering dross, steeped in water for a period of from 24 to 30 hours, thereupon bruised between rollers, or under horizontally moving burrstones ground into a fine paste. The ground (milled) corn is then washed out in cylinder-sieves (as we have already described), *i. e.*, separated into hulls and starch-milk. The latter is placed upon inclined planes, where the starch-granules deposit themselves, while the lighter gluten and fibrin substances are gathered in large tanks. After the water has become clear, and the suspended substances have in greater part deposited themselves, the water is drained off, and the entire deposit thus gained, together with the hulls which have remained in the cylinder-sieves, are used for fodder, which thus produced is rich in azotic nutritious substances, fats, and mineral substances, and hence of great value as feed.

The starch deposited in the gutters is not yet entirely free from azotic ingredients, but already in this condition forms an excellent article for finishing textiles, since it furnishes a good paste.

For manufacturing a finer quality, the starch is taken from the gutters, and the gluten contained therein is dissolved by treating it with alkaline solutions. By a further extended washing in finer sieves, the maize starch can be obtained in a perfectly pure condition.

Inasmuch as the gluten of maize is not by far so tough a substance as wheat gluten, it need never be

dissolved by fermenting, and the process of fermentation is generally dispensed with, in order to obtain a better and more valuable food for cattle and hogs. Notwithstanding this, however, *Watts* uses, by his method of manufacturing corn-starch, a slight fermentation. He leaves the maize to steep in a temperature of from 25 to 60° C. (77 to 140° F.) until a gentle fermentation ensues. The maize is thereupon freed from the liquid above, crushed (bruised) and washed out with water.

By *Leconte's* latest method, maize-starch is prepared in such a manner that the corn is soaked in a solution of caustic soda, and after washing in a wire-sieve, is bruised between millstones, over which water is allowed to stream. The starch-milk thus obtained is conducted through sieves over inclined planes, on which the starch is deposited, while the greater part of the fibres remain in the sieve.

In order to cause a more perfect separation of starch from the maize, sulphurous acid has been applied with favorable results in modern times, and the following directions for making starch from maize can be relied on:—

The maize is, according to its quality and the temperature prevalent, steeped during a period of from 12 to 48 hours in fresh water, the same being frequently renewed, whereby the maize attains a very extraordinary degree of toughness, but at the same time all adhering dross and clay-parts are softened.

After a sufficiently long steeping the maize is washed, while a constant flow of water over it is maintained. For manufacturing corn-starch on a large scale an extra stirring apparatus is used, somewhat similar to the one for the mashing of grain. The

cleansed maize is then bruised, for which operation a crushing roller, composed of three pairs of rollers, is the most suitable. This roller apparatus is constructed as follows: the first pair of rollers consists of extra-hard iron or steel rollers, whose task is the first breaking up or crushing of the maize. The second set of rollers is made of hard iron, and are perfectly smooth, and hence suited to grind the maize fine. The third roller pair consists of cast-iron rollers, and they complete the grinding to a fine paste.

The maize thus bruised to the fineness of common flour is then placed in large vats of from 1 to 1.25 cubic metres (1.3 to 1.63 cubic yards), or from 10 to 12 hectolitres (28 to 33.6 bushels) capacity. Thereupon it is mixed with water containing some sulphuric acid gas, and then left at rest for a period of from six to twelve hours, during which time the starch granules are being entirely laid bare.

The maize paste treated in the manner described, by which the starch is almost perfectly separated from the cellulose, is finally washed out by applying the well-known cylinder sieves, and the raw starch obtained is refined upon inclined gutters.

The largest establishments for the manufacture of starch from maize exist at present in the United States and England.

A description of *A. Erkenbrecher's* celebrated establishment in Cincinnati, Ohio, will doubtless be of great interest to the reader, as by it the magnitude of this traffic and industry may be set forth. The raw material—the Indian corn on the cob—arrives by ship or railroad car directly at the gates of this most extensive corn-starch manufactory in America. The corn is then by an elevator lifted on to scales and, after a cer-

tain weight having been loaded on, the elevator bottom is opened, whereby the maize is caused to descend to a cellar. Here it is received at once on another elevator which carries it up to the fourth story to the grain extracting and separating machines. The loosened grain is then transmitted directly to the subterraneous fermenting tubs, of which there are 25 of 700 bushels capacity each. All the vats and basins are made of marble—not of wood. Meantime another elevator carries the cobs, now freed of corn, 120 metres (131 yards) distance into the coal bunkers, where they are mixed with anthracite coal and used as fuel, furnishing an extraordinarily intense heat. The corn remains in the vats, filled with water, from thirty-six to forty hours, during which time, on account of the ensuing of some fermentation, the gluten is dissolved. The corn is then placed in a moist state between burr-stones while water is pouring over it. The paste thus obtained is ground still finer in another pair of rollers, and receives at the same time an additional supply of water. In the tanks (basins) where the paste is gathered, the starch precipitates to the bottom while the foreign ingredients floating on the surface, such as gluten, hull fragments, etc., are drawn off, and being loaded on wagons, which are in waiting, are carried away to be disposed of as feed for cattle, etc. The starch is frequently stirred, and flows into a system of channels of about 30 metres (33 yards) in length, and 30 centimetres (11.8 inches) in width, and 19 centimetres (7.5 inches) in depth, where its thorough washing is effected. After the starch again deposits itself, it is dug out (the first manual labor), and is then taken in a moist condition to an elevator which carries the starch to the drying-rooms. Here it is first placed

upon warmed bricks and slowly dried, then wrapped up in paper, and by exposure to an increased heat completely dried.

The paste of maize-starch is, as is well known, noted for its great power of stiffening, and the blending whiteness, smooth appearance, and gloss of American linen is the result of the use of maize-starch.

The celebrated and extensive establishment of the *Glen Cove Company* in the State of New York, uses the white species of maize from the Southern and Central States, for the production of two kinds of starch. The finer quality, "*Duryea's Maizena*," appears in the market in the form of a white powder, the second quality is found in commerce as starch in pieces, similar to our wheat-starch. The former, the maizena, being cheaper than any kind of arrowroot, and in quality not inferior, is frequently used as a substitute for the latter.

Maizena is prepared in this establishment from the farinaceous parts; the common starch, however, from the horny parts of the maize grains, but the method used is not known to us.

From maizena most excellent biscuits are made by the celebrated British firm, *Huntley & Palmer* (9 Road Lane, London, and Reading, Berkshire Co.).

The corn-starch manufactory of *Brown & Polson*, in Paisley, Scotland, is among the most gigantic establishments of the kind. Their fabrication is brought into the traffic under the name "Brown & Polson's Corn-flour" in packages of various sizes.

Besides North America and England, corn-starch is also manufactured in South America, especially in Brazil; furthermore, in New South Wales (Australia), and in France and Hungary.

Corn-starch is not only used for industrial and technical purposes, but also as a dietic food.

The Manufacture of Rice-Starch.

Rice (*Oriza sativa**) is the principal plant of culture and the chief means of subsistence for southern climates. The grain is of Asiatic origin. From the earliest records it has formed the principal, if not indeed the only food of a large proportion of the population of India and throughout the Chinese Empire. In Europe it is cultivated in Italy and Spain, while in America, Brazil and the Southern States of the American Union produce it in large quantities. The culture of rice depends besides the warmth of the climate, principally on the fact, that the soil planted with rice can alternately be placed under water (submerged) for an extended period. The rice districts therefore form extensive fields of ground, which if

* The following analysis of rice is by Payen. Air-dry rice contains:—

Starch	86.9
Gluten	7.5
Fatty matter	0.8
Gum	0.5
Epidermis	3.4
Ash	0.9
Total	100.0

The ashes of rice have been analyzed with the following results:—

	Grain.	Husk.
Potash	18.48	1.60
Soda	10.67	1.58
Magnesia	11.69	1.96
Lime	1.27	1.01
Phosphoric acid	53.36	1.86
Silica	3.35	89.71
Peroxide of iron	0.45	0.54

necessary can be submerged. Rice is not a very nourishing food, and a population depending on this cereal for its maintenance requires large quantities thereof to satisfy its wants. On the other hand, rice excels all other cereals by its contents of starch, hence, it is very suitable for the manufacture of starch, especially in those countries where it is raised.

In its air-dry state the contents of starch vary from 70 to 75 per cent. The following analyses of the rice grain are by Payen:—

	I.	II.	III.
Water	12.51	14.6	....
Starch	74.88	76.0	86.9
Dextrine	1.11		
Sugar	traces	....	traces
Fat.	0.78	0.5	0.8
Cellulose	0.76	0.9	4.3
Soluble albuminates	0.41	7.5	7.5
Insoluble albuminates	8.78		
Extractive matter	0 11	....	....
Ashes	0.84	0.5	0.5
	100.18	100.0	100.0

None of all the raw materials that have hitherto been applied for manufacturing starch, is as rich in starch as rice. The single cells of the rice grains, and in these the single starch granules, are so firmly put together one with another, that the separation of the starch from the other ingredients (fibrin, glutinous matter with some albumen, gum, mucilaginous sugar, fatty oils, and alkalies) will not be effected by the mere process of steeping and bruising. This difficulty, however, may be completely overcome by the application of caustic potash or caustic soda lyes.

The inventor of this process of manufacturing starch, especially from rice, is Orlando Jones, who furnishes

for the carrying out of this method the following accurate directions:—

A caustic lye is prepared of potash or soda with lime in the usual way, and the percentum contents of the same of anhydrous alkali are determined by the alkalimetric way (by neutralization of a certain quantity with sulphuric acid); thereupon the lye is diluted by adding pure water, so that one part of alkali is contained in three hundred and fifty parts of water. In five hundred parts of such a diluted lye, one hundred parts of rice are steeped, best in a copper vessel or in iron lined with tin. On one side of the bottom of this vessel a tin cock is placed, whose inner muzzle is covered with a finely perforated plate, by which the rice is retained when the lye is being drained off. After twenty-four hours' steeping the liquid is drawn off by the use of the cock, and when thus withdrawn is replaced by a double quantity of pure water, wherein the rice must be well stirred, and then the water is drained off again in the same manner as before. The rice thus cleaned is put into sieves to drain off all moisture, then ground between the two rollers of a crusher or the stones of a common mill, and it is then by the aid of brushes pressed through sieves. The coarser parts of the rice not having passed through the sieve are again ground and put through it. This operation is repeated until finally only a small residue of bran remains, which is of no use.

The flour thus obtained is carefully stirred in a tin-lined iron or copper vessel with the tenfold quantity of the above described alkaline solution, adding thereto the substance, which may have precipitated from the water used in steeping the whole rice grain.

The mass is then almost uninterruptedly stirred for twenty-four hours, whereby the action of the lye is augmented, but finally it is left to settle for about seventy hours. During this resting in the first place the heavier substances, mineral impurities, sand, etc. precipitate, above this layer the coarser parts of crushed hulls deposit themselves, while the pure starch forms the upper layer. The brownish-yellow, muddy liquid which forms on the surface, contains the dissolved gluten. After being convinced that no further settling is taking place, this liquid gluten is drawn off with great care by applying a tin siphon, without stirring up the sediment. Finally this sediment is mixed with double the quantity of water as of the lye solution previously used. This having been attended to, the mass is permitted to rest for one hour, to allow the heavy fibrous parts to precipitate, while the starch is still suspended. The starch containing milky liquid is then—by means of the siphon—poured through a series of silken sieves, whereby the fibres and foreign ingredients are kept back, while the starch containing liquid runs into large vats.

The impurities deposited in the first vat, still containing much starch, are mixed with water, and the same process is repeated as before, in order to free the starch as much as possible from the fibrous substances. By repeated depositing and decanting, whereby the liquid is always strained through fine sieves, new portions of pure starch-milk are gained, which are, as a rule, added to the first milky liquid.

In the large depositing vats, which hold the refined starch-milk, the pure starch precipitates thoroughly within seventy hours. It is perhaps once more washed with fresh water, and thereupon placed in baskets or

bags to let the water drop off, and finally dried in the same manner as wheat-starch.

The bleaching of the rice-starch usually takes place prior to the drying.

H. Ransford applies an alkaline liquid for the fabrication of starch from rice, in which he soaks the rice in order to dissolve the albuminous parts contained therein. Instead of permitting the liquid—as Jones does by his method—to rest with the rice, Ransford keeps it in motion. This is done, either by letting the solution of lye run out from the top of the tank, and by means of a pump forcing it back in the lower part through a perforated bottom, or using for this operation a tight tank, in which by means of a pump the alkaline liquid is forced in, until a pressure of 20 pounds per square inch is caused inside of the tank. This operation is repeated with a renewed supply of lye, after previously draining off a part of the liquor. When the rice is perfectly saturated by the lye, it is taken out therefrom, and to remove the gluten the substance is placed in bags of suitable texture and subjected to pressure, whereupon it is ground fine and then manipulated for obtaining the starch, as set forth above. To free the starch obtained from rice, of its water, Ransford recommends the use of flat metal vessels (boxes), with perforated bottoms. These boxes are, by partitions made of plated zinc, divided into sections, and so arranged, that, from the space beneath the perforated bottom, the air can be pumped out. The perforated bottom of the vessel is covered with a thick cloth. The starch, appearing usually mixed with some pigment, is, after the water has been drawn off, placed in the vessel, and underneath the same a vacuum is produced by the application of an air-pump. By the outer pressure of air,

the greater part of the water contained in the starch, along with the albuminates which may still be contained therein, is pressed through the perforated bottom into the lower part of the box. By the partitions of these boxes, the dried starch receives a similar shape, as is the case in the much used filter boxes, that is, the starch forms in long bars. These are cut up into smaller pieces and dried in the well-known manner.

Berger's treatment is similar to the method of *Jones*. 100 kilogrammes (220 pounds) of rice are steeped for two days in water, then ground and mixed with sufficient water to form a milky liquid, then poured through a sieve with 8½ openings to the square centimetre (0.155 sq. inch). Those parts of the rice which do not pass through the sieve are again placed in the mill to be reground. The milky liquid is then mixed with a solution of 7.5 kilogrammes (16.5 pounds) of carbonate of soda in 5 parts of water, permitted to settle for four hours and again stirred. This operation is repeated until the rice has been at least 60 hours in contact with the alkaline liquid. The mass is then left to rest for 18 hours. During this period, the starch precipitates to the bottom, while the greater part of the gluten and other foreign ingredients dissolves, and is removed by a siphon. This treatment with soda lye is again repeated, in order completely to remove the soluble ingredients of the rice. Thereupon follows the process of washing, as in Jones's method, for removing the sand and other foreign admixtures, and finally the pure starch thus gained is repeatedly washed out in water and dried.

Berger also produces rice-starch by the process of fermentation, in this manner: The rice is left to steep from five to six days, then ground, the flour mixed

with water, and this left to ferment so long that the gluten is in such a condition that it can be removed by washing it out. But this method is not much used.

A similar process is that of *Colman*, by which for every 100 weight parts of rice-flour mixed with water, 15 weight parts of the sour residue obtained during the operation in the pressing of wheat-starch, are mixed. The fermentation process is, as becomes evident, very much advanced thereby.

The American method of obtaining starch from rice is as follows: The rice is steeped in wooden boxes or vats with a caustic soda lye of 1.75° B., and remains therein for eighteen hours, while being frequently stirred. The dirty, yellowish lye is then withdrawn; passed through a long, flat, but little inclined channel or gutter, upon which a starch containing mucus settles. The further manipulation of this mucus, as well as that of the lye, will be described anon.

The rice, which must be so soft that a sample thereof can be easily bruised between the fingers, is repeatedly washed out with water, and under a stream of greatly diluted caustic soda lye, ground into a thin paste. This paste is transmitted from the mill to the flour-vat, whose stirring apparatus remains running for the space of six hours. After the lapse of this time the mass is allowed to rest for twelve hours, whereby, on the one hand, a more perfect loosening of the gluten is effected, and otherwise a thickening of the mass by the separation of clear lye results, which latter is removed by application of a siphon. The thick paste is thereupon by means of the raw-starch centrifugal apparatus "hurled," the drum being filled to two-thirds of its capacity with rice-paste, and for fifteen minutes kept in rotation. After the drum is brought to a halt, the

dirty, yellowish alkaline gluten solution of course accumulates on the bottom of the same, and can be drawn out by opening the holes in the bottom which had been closed during the act of "hurling." The further use of this lye, and of the gluten-starch, will be defined below, and we here only state that the drained-off liquid may be again used for steeping new lots of rice.

Corresponding to the various specific weights of its ingredients a sharp line of division of the paste appears in the apparatus. Closely to the sides of the drum the white raw starch hangs, and on this the grayish-white gluten-starch.

The buildings used by the American rice-starch manufacturers have, besides the basement, usually three more stories. The white, solid raw starch is usually taken from the centrifugal machine in the basement, aud by means of an elevator hoisted into the third story, and put into the stirring vat in order there to be stirred up in a weak alkaline solution. After effecting a thorough mixing, the starch-milk is passed through a cylinder sieve, of known construction, into the washing-out vats of the second story, where the further refining of the liquid, which has been allowed to settle for a short time, takes place. The starch-milk is now drained off and flows into the depositing vat on the ground floor. Another straining will in most cases not be necessary, but it is imperative to make the necessary arrangement which, however, has not to serve merely for this purpose alone.

In the depositing vat, last mentioned, the starch is allowed to settle until it is deposited perfectly firm; the period in which to effect this is from twenty-four to thirty-six hours. After this is accomplished, the clear liquid is drawn off, the stirring up with some water is

repeated, and the starch is refined in the centrifugals which are placed in the basement. It is, however, according to the experience of some experts, not at all profitable to use the refining centrifugal apparatus, although it furnishes the starch almost entirely air-dry, because the pieces acquire after drying a peculiar rough surface when broken up, and do not suit for the manufacture of crystal starch on account of their form. A further cause is, that the light dross, which is sometimes suspended in the lye solution, is forced together through the whole starch cake to the outer line, whereby portions of the dross become mixed in with the starch. Hence the latter loses at least its even appearance. For this reason it would be best to use, for the final process of refining, the centrifugal apparatus with closed sides, by which the gluten and dross remain in the middle and can be easily removed. The removal of these impurities is effected by careful washing, and with the aid of a soft brush, and the starch may now be placed in the filling boxes. To insure the evenness of the product it is necessary again to place such pieces in a vat, which is placed at an equal height with the above-mentioned one in the second story of the building. Here the mass should be stirred while adding water enough to make a thin milk, and finally passed through the reserve-cylinder sieve into boxes lined with dense cloth.

In order to simplify the filling of the boxes, the following method should be observed. The perforated filling boxes of 1.25 metres (4.1 feet) in length and lined smoothly with linen cloth, are placed on wooden frames in the basement of the factory. The bottoms of these frames are, towards the centre, gutter-like deepened and lined with tin. The surplus starch-milk

must therefore run there and can be conducted to a lower floor. The projecting end of each cloth is put over the rim of the adjacent box. The rims of the boxes forming the sides are raised 5 centimetres (1.97 inches). The ends of the cloth are thrown across lathes in such way as the direction of the flowing starch-milk requires. If the latter is now permitted to run in on one side, it will enter from the first box into the second, and so on until the entire set of boxes is filled in succession.

The further manipulation of these pieces, particularly suited for producing crystal starch, is essentially the same as the one already defined. The residue which remains in the separating vat (in the second story) consists in greater part of gluten-starch with cellulose hulls and not sufficiently bruised particles of rice. It is stirred up in water and allowed to flow through the cylinder sieve into a vat stationed on the first floor, where the process of fermentation takes place, while the pieces of rice are kept for regrinding.

A similar manipulation is customary with the so-called "third product" being the substance scraped from the centrifugal apparatus after the first operation. It is brought by an elevator into the second story, and placed in a vat, stirred with water, and flows also through the cylinder sieve into the above-mentioned fermenting vat on the first floor. After a thorough edulcorating, the fermenting is brought on by means of putrefied wheat gluten. The fermentation, being at first of an alcoholic nature, is soon transformed into the acetic fermentation, whereby the solution of the gluten ensues. After the fermentation is complete the treatment is the same as already described.

It is necessary that the rooms used for fermenting should form separate apartments, and not be connected with those where the fermenting must be avoided. The diverse vats may be on the same floor with the steeping tubs, but also separated from these. The easy introduction of warmth is of course desirable. The principle of a terrace-like order for the whole establishment requires, that the steeping tubs be placed above the mill, and the receiving vats above the centrifugal machines. If the height of the latter apparatus (situated in the basement) is inclusive of the brick beds 1.4 metre (4.6 feet), the declivity from the bottom of the receiving vats to the centrifugal machine and likewise from the overflow of the mill to the receiving vats each 0.3 metre (0.98 foot), then that outlet must have a height of 3 metres (9.84 feet) from the basement.

Sulphurous acid is, when well prepared, the best means of suppressing putrefaction. The same effect is produced by sulphite of soda, while a calcium salt may be applied in cases where a formation of gypsum no longer works injury.

The weak solution of lye which flows out from the centrifugal machine during the first operation can be again used for a renewed steeping of rice. In this case its contents of caustic soda are analyzed, and any percentage needed is added by a supply of fresh lye. In conclusion we will yet mention a method invented by *Rehe*. According to this, the rice is prior to steeping heated to from 60° to 70° C. (to 140°–158° F.). Then it is steeped, ground, and, in order to dissolve the gluten, it is treated with 8 kilogrammes (17.6 lbs.) of soda, for each 100 kilogrammes (220 lbs.) of rice.

Besides the species of grains and corn, which we

have described, and from which commercial starch is produced to advantage, there are yet quite a large number of plants and parts of plants which yield starch in various quantities; but none of them sufficient or of a corresponding quality to guarantee favorable results for working them on an extensive scale. It is therefore deemed sufficient simply to name these raw materials from which starch can be obtained. They are as follows: Chestnuts, barley, rye, oats, leguminous plants, buckwheat, bran, the imperial lily, arrow-root, moss, lichen, sea-weed, sago, tapioca, wood, acorns, unripe kernel fruit, and several other plants.

Discernment and Determination of the Various Kinds of Starch.

When we consider that starch is so extensively distributed, and found in the most distinct species of plants and parts thereof, it cannot possess in all cases identical properties. As to their chemical composition, the different kinds of starch are entirely identical, and if a difference should be found it can only result from foreign substances, which adhere to the starch. But this is not the case as regards the physical properties of the different kinds of starch. These diverging appearances of the diverse sorts of starch, make it possible to classify and distinguish them.

For the purpose of distinguishing the various kinds of starch as well as to test them with regard to adulterations, we use in most cases the microscope.

The following interesting table will be useful for a classification of the various kinds of starch, as to their forms and respective sizes:—

A. Grains simple, entirely rounded off on their surfaces.

1. Kernel central; layers concentric and predominantly disk-shaped, on the side lentil-shaped; kernel rounded or radiating slit.

Wheat-Starch.

Large grains, 0.0352 (0.001386 inch) to 0.0396 millimetres (0.001559 inch).

2. Kernel eccentric, position of layers plain or meniscus-shaped, as with the cereal.

Potato-Starch.

Nucleus mostly on the narrower end, 0.06 (0.00236 inch) to 0.10 millimetre (0.0039 inch).

B. Grains single or combined. Single granules, with respect to the separated granules either entirely bounded by even surfaces, polygonic or only partly so, with rounded surfaces.

Granules throughout polygonic.

Rice-Starch.

Many with large kernel cavity. At most 0.0066 millimetres (0.00026 inch).

Maize-Starch.

Among polygonic, also rounded forms. Mostly with extensions or star-shaped kernel cavity. All granules free.

The *Wheat-Starch* of commerce in its natural condition forms mostly very white, irregular-shaped, polygonic, and often more or less oblong and dry pieces, hard to crush or bruise between the fingers; when crushed it forms a crystal-white, dull, not crummy or loose powder, of some bluish hue. Viewed through a magnifying glass or microscope, the wheat starch

grains also appear glossy, especially under a glaring light, but not in such a high degree as the granules of potato-starch. Under the microscope the wheat-starch granules show a more or less spheroidal rounded form of diverse sizes. The central part of the concentric layers of the granules are only discernible by means of a 500-fold magnifying power.

To distinguish between wheat-starch and the cheaper potato-starch is, by the application of the microscope, easy. The granules of the potato-starch are larger than those of the wheat-starch, and have an irregular, mostly pear-shaped form. The central part, as well as the concentric layers, can be discerned in the potato-starch even by the use of a magnifying glass of 200- to 300-fold power.

The action of chemicals on the wheat-starch is characterized by the following results: If 1 gramme (15.43 grains) of this starch is mixed with a liquor of 6 cubic centimetres (1.62 fluidrachms), containing 25 per cent. muriatic acid and 4 cubic centimetres (1.08 fluidrachms) water, then, by shaking the same for ten minutes, a gelatinous mixture is formed, which does not possess any cabbage-like odor, like the potato starch. One part of wheat-starch mixed with 100 parts of boiling water, forms a colorless, somewhat milky mucus, with a bluish hue.

The commercial potato-starch forms powder-like crummy fragments, which easily fall to pieces, and can be still easier crushed between the fingers. The powder is of a fine grain, by the light of the sun of a silky sheen, but of less whiteness than wheat-starch; its white color has always a yellowish tone. Under the microscope the potato-starch granules appear larger than those of wheat-starch, more oval or pear-shaped,

and marked with shell-shaped lines, drawn around a centre (nucleus), usually lying on the narrower end of the granule. Potato-starch has a greater specific gravity than wheat-starch.

The action of chemicals on potato-starch we have already investigated while explaining that of wheat-starch, and but little in this respect has to be added. If we boil 1 part of potato-starch in 100 parts of water, we obtain a transparent paste with grayish tone of color, which, however, does not appear milky as with wheat paste. If 1 gramme (15.43 grains) of potato-starch is well shaken up in a mixture of 6 cubic centimetres (1.62 fluidrachms) of pure muriatic acid of 25 per cent., and 4 cubic centimetres (1.08 fluidrachms) of water, then a jelly is formed, which has a peculiar cabbage-like odor, or like that of the fresh unripe hulls of beans.

Further characteristics of wheat- and potato-starch are the following:—

Wheat-starch is less hygroscopic than potato-starch, since the former contains in the air-dried state but 12 to 14 per cent., the latter, however, 16 to 18 per cent. of water, which it will reabsorb from the air, even if it has been dried very carefully.

The specific gravity of both kinds of starch is exactly the same, to wit, 1.53. In many cases, the great difference in the diameter of the single starch-granules will explain the origin of the starch.

The stiffening power of wheat-starch is greater than that of potato-starch, and for this reason it is preferred for stiffening linen and washed clothes as well as for making bookbinder's paste. In the paste the starch-granules are contained in the form of gelatinous lumps, which in the potato-starch are much larger than in

wheat-starch; this causes the trouble that the textiles, having been stiffened with potato-starch, while being smoothed (or ironed) will not look so well, as the hot iron sometimes shoves off these miniature lumps, or balls them together, which never occurs when wheat-starch is used. The paste of wheat-starch exposed to the air remains unaltered for a long time, while potato-starch paste, after but a few days, separates a gelatinous mass, over which an aqueous and somewhat sour liquid forms. The mass mixed again by stirring with this liquid no longer possesses the same sticky nature which the fresh paste had. Wheat-starch is therefore preferable to potato-starch, and would have long since supplanted the latter entirely, if the former were as white and pure and as cheap as potato-starch.

As has already been stated, the paste formation of potato-starch ensues at 46° to 62° C. (114.8° to 143.6° F.), while wheat-starch turns into paste at from 50° to 67.5° C. (122° to 153.5° F.). In its dry state, potato-starch forms a more voluble powder than wheat-starch. In water potato-starch precipitates much faster than wheat-starch, which latter when taken out of the water forms, when dried, coherent angular pieces.

Frequently the starch of the grain species, particularly of wheat, is considered as the purest; this is nevertheless erroneous, since potato-starch can be produced in a much purer condition, because no removal of the gluten brings difficulties as is the case with wheat-starch. This is also the reason why commercial wheat-starch always appears more or less mixed with gluten.

Corn-starch is characterized by its extraordinary power of stiffening, exceeding that of wheat-starch

in a high degree. Corn-starch also stiffens textile fabrics more uniformly than wheat-starch.

Chemists of great celebrity have thoroughly investigated the action of iodine vapors on the diverse kinds of starch, the results of which are herewith given:—

In order to ascertain the reaction of iodine with accuracy, we apply a square-shaped glass or porcelain vessel of 1 centimetre (0.394 inch) high, and 10 centimetres (3.94 inches, wide. Into this vessel we pour 2 grammes (30.86 grains) of iodine, with 20 grammes (308.60 grains) of fine sand, placing over it an air-tight fitting glass plate on which a thin layer of the starch, mixed with some little water, is put by means of a fine brush. The coloring of the starch begins within a few minutes thereof, whereupon the glass plate is taken off, and after the starch layers have become dry the shade of the color is examined.

By the influence of the iodine vapors on sundry kinds of flours and starches, the following shades of color resulted:—

Wheat-starch . . . violet.
Potato-starch . . . turtle-gray.
Dextrine . . . . . showing no change of color.

From this it becomes manifest that these reactions may in many cases be of useful service, as, for instance, in the case of starches from wheat or potatoes. But some mixtures of wheat-starch with potato-starch cannot be detected in this manner, since if the admixture amounts to less than one-fifth the color test can no longer be relied on.

Gobley's method of testing possesses, however, above all others the advantage of being more easily carried out. It serves especially for the purpose of examining

the sizing paste prepared from starch which is used in the printing of calicoes.

Mayet has made experiments with regard to the action of caustic potash on the various kinds of starch, and has rendered an account, by which they are examined, and ascertained with tolerable accuracy; provided, however, they were pure and unmixed previous to the test. According to this method 5 parts of the starch to be tested are mixed with 5 parts of a 25 per cent. solution of hydrate of potash, previously diluted by 60 parts of water. By this method the following results are obtained:—

Potato-starch furnishes a strong, opalizing, transparent substance which forms a stiff jelly within half a minute.

Wheat-starch, or starch of the grain species generally, does not become stiff even after the lapse of thirty minutes, rendering a milky entirely dull mixture, from which no starch precipitates.

Quality.—Test as to Impurities and Adulterations contained in Starch.

The amount of fixed Water in Starch.—The amount of water contained in starch is very varying. In its *green state*, that is, when freshly prepared and deposited in the washing vessels, and then left to lie for from 24 to 36 hours on a water-absorbing surface (for instance, gypsum plate), starch will contain approximately 45.5 per cent. of water, of which nothing can be further removed by pressing. When regularly dried and than exposed to a damp atmosphere of 20° C. (68° F.) for a period of several days, it will contain an average of

35.75 per cent. of water. Stored in a dry magazine its contents of moisture amount to 18 per cent. Totally dried at a temperature of 100° C. (212° F.) in a space void of air, it contains finally no trace of water.

The fixed water of a good commercial starch should not exceed 18 per cent. By drying a weighed quantity of such starch over a water bath, it should not lose much more than 18 per cent. of its weight. In purchasing starch it is of great importance to know accurately its contents of water, since finally the value of the starch according to its contents of water, is very varying.

Several methods of ascertaining the contents of water in starch have been proposed, of which that of *Scheibler* deserves the first consideration. His method is based on the principle that a starch containing more than 11.4 per cent. of water, imparts this surplus of moisture to alcohol of 90° Tralles = 0.8339 specific gravity, while a starch of less moisture absorbs so much water from this alcohol until it has absorbed enough water to form 11.4 per cent. The increase or decrease of the watery contents of the alcohol applied, is found in the change of its specific gravity, and this becomes thus a measure for the contents of water of the starch to be tested.

To carry out such a test 1 weight part of starch is taken, and over it double its weight of alcohol is poured, weighing in a normal temperature exactly 90° Tralles, shaking it repeatedly for one hour's time, whereupon it is filtered, and the specific gravity of the alcohol flowing off accurately ascertained. To simplify this method measuring of the alcohol may be substituted for weighing. For each 100 cubic centi-

metres (3.38 fluidozs.) of alcohol of 90° Tralles = 83.39 grammes (2.92 ozs. avoird.) $\frac{83.39}{2}$ = 41.7 grammes (1.46 ozs. avoird.) starch should be taken.

The changes thus produced in the specific gravity of the alcohol used by the varying amount of water in the starch, are fixed by a series of experiments, and the following table has been prepared in accordance therewith. It will only be necessary, therefore, to find the figure next that found as the specific weight of the alcohol, and the amount of water of the sample of starch to be tested is ascertained at once.

Table for ascertaining the contents of water in Starch.

Water contents of the starch. Weight p ct.	Specific gravity of the alcohol.	Water contents of the starch. Weight p. ct.	Specific gravity of the alcohol.	Water contents of the starch. Weight p. ct.	Specific gravity of the alcohol.
0	0.8226	22	0.8455	44	0.8643
1	0.8234	23	0.8465	45	0.8651
2	0.8243	24	0.8474	46	0.8657
3	0.8253	25	0.8484	47	0.8665
4	0.8262	26	0.8493	48	0.8673
5	0.8271	27	0.8502	49	0.8680
6	0.8281	28	0.8511	50	0.8688
7	0.8291	29	0.8520	51	0.8695
8	0.8300	30	0.8529	52	0.8703
9	0.8311	31	0.8538	53	0.8710
10	0.8323	32	0.8547	54	0.8716
11	0.8335	33	0.8555	55	0.8723
12	0.8346	34	0.8563	56	0.8731
13	0.8358	35	0.8571	57	0.8738
14	0.8370	36	0.8579	58	0.8745
15	0.8382	37	0.8587	59	0.8753
16	0.8394	38	0.8595	60	0.8760
17	0.8405	39	0.8603	61	0.8767
18	0.8416	40	0.8612	62	0.8775
19	0.8426	41	0.8620	63	0.8783
20	0.8436	42	0.8627	64	0.8791
21	0.8446	43	0.8635	65	0.8798

For practical use Scheibler has constructed a hydrometer by means of which the density of the alcohol before and after the experiments can be ascertained, and from its scale the degree of water contained in a

sample of starch can be read according to percentage. A percentum thermometer combined therewith permits of a correction caused perhaps by a deviation from the normal temperature. Of late an instrument has been constructed by *Block* which is designed more especially for testing the water contents of potato-starch. The instrument is termed a "*Feculometer*," but is not of as much value as the first described contrivance, inasmuch as it does not accurately determine the contents of water in starch, but indicates with certainty whether the article is pure or spoiled.

Testing the Starch as to its Impurities with reference to Adulterations.—The various kinds of starch as they appear in commerce are frequently mixed with flour of the various grain species and other foreign substances of organic as well as mineral origin, *i. e.*, are adulterated.

The mixing of starch obtained from different kinds of raw material, as also its adulteration with flour, can in most cases be proved by means of a microscope. As is known, the various kinds of starch are distinguished by certain characteristic formations, while the flour of any seed species also contains, besides the starch-granules, the fragments of the seed coats and of the hulls. Besides the microscopic method, such impurities and adulterations of the starch may also be proved by the application of certain chemical reagents.

A series of experiments for the purpose of testing the adulterations of starch with sundry flours and minerals has been made by means of *Gobley's* iodine reaction, with the following results:—

Potato-starch mixed with wheat-flour obtains—exposed to the vapors of iodine—a somewhat bluish color,

which, however, only appears plainly when the flour admixture does not exceed 40 to 50 weight per cent.

Wheat-starch adulterated with but a small quantity of flour cannot be detected, but if the flour admixture is increased, the violet coloring—caused by iodine vapors—decreases in clearness, and if the starch layer is allowed to dry, black specks will become visible, which in pure starch are never noticed, and therefore always indicate the presence of flour.

Wheat-starch mixed with one-third potato-starch furnishes in comparison with the reaction of the pure wheat-starch a scarcely traceable difference; but this deception becomes more manifest when the mixture is stirred in hot water. Wheat-starch mixed with roasted flour in the proportion of one part to one-third shows in the coloring a very considerable difference; the color is duller, and black specks are visible. Starch mixed with gypsum can be detected at once, because the gypsum does not color at all, but shows white specks, proving the presence of a body upon which iodine has no influence. It may, however, occur that by this test the starch strata happen to lie somewhat thick, and the gypsum may be entirely covered thereby, so that in this case the want of coloring of the entire mass cannot be noticed. The process of burning such starch to ashes is, therefore, always preferable to the iodine reaction.

Starch adulterated with sulphate of zinc or copper cannot be tested by the iodine process. The adulterations of the various sorts of starch can in many cases also be tested by means of caustic potash. Wheat-starch and potato-starch mixed in equal weight parts, treated according to this method, furnished a semi-

transparent gelatinous substance which became solid within two minutes.

Four weight parts of wheat-starch with one weight part potato-starch furnished a very dense, opaque, and milky mucilage.

Four and a half parts of wheat-starch with one-half part of potato-starch rendered an opaque, milky mucilage, although not as thick as the former, but still distinguishable from that formed with pure wheat-starch, by not running off in drops from a glass tube as the latter does.

Very frequently starch is adulterated with various mineral substances, especially with ground gypsum, with glauber salt that has lost its crystallization water, etc., less frequently, however, with powdered terra alba, white marble, chalk, white clay, and bolus and sulphate of baryta.

Whereas the ashy contents of pure starch, whether manufactured of potatoes or grain, etc., are but very insignificant, the determination as to mineral admixtures can be simplified by the *incineration* of a certain weighed quantity in a flat vessel. The ashy residue is weighed and calculated by percentage. A residuum exceeding but 1 per cent. of the weight of the starch burned, proves the admixture of foreign substances.

The presence of gypsum or terra alba is best ascertained by a solution of chloride of barium. To this end the starch is mixed with water, shaken, filtered, the liquor treated with the solution of chloride of barium. If gypsum or terra alba is present, it will form a white precipitate, which is insoluble in muriatic acid. The presence of *chalk* is most suitably tested by means of muriatic acid. When over the dry starch muriatic acid is poured, it will cause effer-

vescence, and the solution thus gained when treated with oxalate of potassium will furnish a white precipitate.

Clay is not soluble in diluted muriatic acid, or is but very slightly so, and baryta not at all. A sample of the residue, when not ascertained as gypsum, heated on burning charcoal, furnishes when moistened with muriatic acid a substance smelling like sulphuretted hydrogen; while the muriatic acid solution becomes dull and muddy when sulphuric acid is added thereto, and thus proves the presence of sulphate of baryta. Neither of these two reactions results if clay is the means of adulteration.

Application of Starch.

Starch is applied for multifarious purposes. The best qualities serve for the sizing of paper, in the manufacture of this article, especially for preparing fancy papers. How large the demand for starch is for the manufacture of paper, can, for example, be gleaned from the fact that to the paper mass, which serves for the production of fine paper, usually from 10 to 15 per cent. green, or from 7 to 8 per cent. dry starch is added. Thus a paper mill, producing daily from 1400 to 1500 kilogrammes (3080 to 3300 lbs.) of prime quality paper, will use annually from 50,000 to 75,000 kilogrammes (110,000 to 165,000 lbs.) and more of green starch.

For the manufacture of white glucose-syrups, for finishing textiles, for making white dextrine, as well as for preparing farinaceous food and fine pastry, etc., the finest, perfectly pure starch is used. On the other hand, the more inferior sorts are used for the same

purposes when the quality of the product is not of such vital importance, as, for instance, for weaver's dressing, as means for thickening the strong alkaline solutions (mordants), and coloring substances for cloth printing, for the manufacturing of noodles and macaroni, in lieu of tapioca, sago, etc. Starch forms, furthermore, that substance from which, by the influence of certain agencies, as diastase, etc., sugar, and from it alcohol is produced. It forms, therefore, the raw material for the production of ardent spirits (brandies, whiskeys), and beer and ale, etc.

Another important application which starch finds is in the powdering (dusting) of the forms in metal foundries. It serves in this respect in lieu of the charcoal-dust formerly used, a material very injurious to the health of the workmen. Starch generally, but more particularly that made of potatoes, is an excellent food for silkworms, and is for this reason thrown on the foliage of mulberry trees. The use of starch for stiffening (*starching*) linen and washed clothes, is so well known that we deem it superfluous to dwell upon it. On account of its greater cheapness potato-starch is consumed in larger quantities than wheat-starch. Nevertheless, great quantities of the latter are steadily produced, because it has for certain applications advantages which the potato-starch lacks. It stiffens and pastes much better, swells up better, and as a rule is whiter than potato-starch. It serves, therefore, especially for finishing white textiles, for bookbinder's paste, and for baking fine pastry. For calico printing wheat-starch is also best suited for some colors, while potato-starch, on the other hand, is more applicable for finishing those textiles whose colors are less delicate to manipulate, and in general

for those uses where a large amount of adhesive power or delicacy of color is of no great consequence.

In conclusion, we deem it of some interest to annex a tabulary synopsis of the various operations necessary for the manufacturing of starch.

Preparation of the wheat.
Steeping of the wheat until it becomes soft.
Pressing, washing, and bruising.
Washing out and assorting the starch.
Pressing of the fine starch.
Gathering and edulcoration.
Elutriation and assorting of the commoner starches.
Drying of the starch in brick-shape.
Breaking up.
Finishing the process of drying upon frames.

Preparing corn and rice for starch is identical with the above manipulations of wheat. It should be added, however, that the finest quality of starch in the case of wheat is finished in 11½ days, and that of maize in 15 days, and hence by far the greater part of the entire fine product is finished much earlier than is the case with the medium and ordinary 'ones.

PART II.

THE MANUFACTURE OF STARCH-SUGAR.

SECTION I.

THE CHEMISTRY OF STARCH-SUGAR.

History, Literature, and Terminology. — Professor Kirchhoff, of St. Petersburg, Russia, made, in 1811, the important discovery that starch boiled in diluted sulphuric acid is transformed into sugar.* Soon after this discovery great efforts were made to simplify the process of Kirchhoff for making sugar, in order to produce this article as cheaply as possible. The origin of glucose manufacturing occurred at the time of Napoleon I., when the English were blockading the Continent, and it caused, therefore, a great and general sensation, as it was thought at that time that grape-sugar was identical with cane-sugar, and hence could in every respect be substituted for that product.

This new branch of industry was, therefore, pursued with rare energy, and immense quantities of such starch-sugar were manufactured; and this industry

* Already Foulcroy and other chemists knew that starch, when treated with acids, becomes transformed into a gummiferous substance. At a later period, when gum was a very expensive article, Nasse, who co-operated with Kirchhoff, found, as he was experimenting for the purpose of producing gum from starch, instead of gum, sugar, without this being his intention.

offered at that time, on account of the blockade, manifold opportunities for establishing extrordinarily well-paying enterprises.

But when it was subsequently proved that starch-sugar was by no means identical with cane-sugar—being less soluble, of less sweetness, and not at all suitable to serve as a substitute for the former—then this product was for a number of years without demand, although it had already at that time been recommended for the manufacture of spirituous liquors and for brewing beer.

Only in more recent times, when in consequence of the greater propagation of the beet-sugar manufacture, the want of molasses syrup became more and more felt in Europe (since the East India syrup could not be supplanted by the sugar-beet syrup), the manufacture of glucose-syrup as well as starch-sugar received more attention. The importance of this industry was at once understood, and it is at present carried on in many countries with great success. This industry is especially flourishing in Austria and Germany, where large establishments of the kind exist in Brandenburg, Frankfort on the Oder, Kustrin, and in Saxony, while the principal factories in this country are in Buffalo, Chicago, St. Louis, Peoria, Ill., and Danville, Ill. The raw material is furnished in some cases from a great distance. How much this branch of industry has been developed in modern times, can be gleaned from the fact that Germany alone in the year 1876 produced in her 47 glucose and starch-sugar syrup factories, from 41.75 million kilogrammes (91.85 million lbs.) of green, and 5 million kilogrammes (11 million lbs.) of dry starch, 14.8 million kilogrammes

(32.56 million lbs.) of syrup, and almost 11 million kilogrammes (24.2 million lbs.) of solid grape-sugar.

The literature treating on this interesting subject is abundant, and from the discovery of glucose in 1811 up to the close of the year 1880, many volumes have been published in the various languages of continental Europe.

The terminology grape-sugar, starch-sugar, potato-sugar, uric-sugar, dextrose, glycose or glucose, comprises the following species of sugar:—

1. The diabetic sugar.
2. The solid honey sugar.
3. The sugar which by means of diastase or acids is produced from starch and similar substances.
4. The products of the action many acids have on cane-sugar, and
5. The sugar contained in many fruits. All of these species show in their pure state and freed of the uncrystallizable species of sugar adhering to them, the same forms of crystallization as well as the same circular-polarization.

In France the following names are in vogue:—

a. "Glycose," according to Dumas, is the generic name for grape-sugar and starch-sugar, as fully identical sugar species.

b. "Starch-sugar" or "starch-syrup" is the solid or liquid sugar prepared from starch by the aid of sulphuric acid.

c. "Dextrine-sugar" and "dextrine-syrup" are the names given to the solid or liquid product obtained by the influence of diastase on starch.

Wherein found and in what percentage.—Sugar is found in nature in three different forms, as so-called

cane-sugar, grape-sugar, and mucilaginous sugar (likewise called fruit-sugar, levulose, or chylariose).

Grape-sugar is largely diffused throughout the vegetable as well as the animal kingdom, and is found in most of the sweet-tasting fruits, and in many parts of plants in larger or smaller quantities. It is contained in the honey of the bee, and is separated in large quantities in the urine of those unfortunates who suffer from that disease of the kidneys known as *diabetes mellitus.** In the various kinds of fruits grape-sugar is found in the following quantities, shown in the mean figure, viz.:—

Apples	7.28–8.37 per cent.
Apricots	1.80
Pears	7.45–10.80
Blackberries	4.44
Strawberries	5.78
Whortleberries	5.78
Raspberries	4.00
Currants	6.10
Mulberries	8.19
Mirabelles	3.58
Peaches	1.57

* The *saccharine compounds* belong more exclusively to one physiological class than any other of the organic constituents of the body. *Glucose* or "grape-sugar" is the form in which saccharine matter is normally present in the blood and chyle. Cane-sugar when introduced into the system, passing into the circulatory currents, is neither assimilated nor removed by combustion, but finds its way out of the system, essentially unchanged, by way of the kidneys; on the other hand, glucose, even when introduced into the system in much larger quantities, is entirely appropriated to useful purposes, not a trace of it being discoverable in the excrements. Indeed, when an insufficient quantity of the required sugar is received in food, the liver generates liberal supplies from starch and other sources. The liver is the chief sugar-creating organ, but the protëin compounds, in certain stages of decomposition work in the same direction.

Plums	2.12 per cent.
Greengages	3.12
Sour cherries	8.77
Sweet cherries	10.79
Gooseberries	7.15
Grapes	14.93
Prunes	6.26

In the sweet sap which accumulates in the honey cups (nectarines) of plants, fruit-sugar is found—mostly along with cane-sugar—in great quantities. By the organism of the bee, however, the cane-sugar is transformed into grape-sugar.

Formation.—Grape-sugar is not only found in nature, but can also be produced chemically. Thus it is formed as a result of the action of diluted acids, diastaste, gluten, saliva, etc., on starch, and for this reason starch is used for its production, in the first place.

Pure starch is composed, as is well known, and expressed by the formula—

$$C_{12}H_{20}O_{10}, \text{ or } C_{12}H_{10}O_{10}.$$

If the starch absorbs two molecules of water, it becomes transformed into glucose (grape- or starch-sugar), according to the formula

$$C_{12}H_{24}O_{12}, \text{ or } C_{12}H_{12}O_{12}.$$

By comparing the chemical composition of the starch, as also that of the cane-sugar and grape-sugar with each other, we will notice at once, that between these three combinations an intimate affinity exists, and that cane-sugar, as regards its composition, is between starch and grape-sugar, *i. e.*, it contains one molecule more water than starch, and one molecule less than the starch-sugar, according to the following formulæ:—

$C_{12}H_{20}O_{10}$, or $C_{12}H_{10}O_{10}$ = Starch.
$C_{12}H_{22}O_{11}$, or $C_{12}H_{11}O_{11}$ = Cane-sugar.
$C_{12}H_{24}O_{12}$, or $C_{12}H_{12}O_{12}$ = Grape-sugar.

In the same manner as diluted acid, when heated, acts upon the starch in transforming it into glucose and dextrine, so also other organic substances, especially diastase, gluten, mouth and intestine saliva, blood serum, kidney substance, gall, etc., will cause a like effect.

This same process of transformation we observe also in the germination of seeds, as in the tubers and bulbs of many plants; the starch is transformed into sugar and diastase, which therewith furnish to the developing young plant the first organic nutriment. A similar transformation takes place in the starch of the potato when it freezes, which explains the sweet taste of such potatoes.

Saussure has drawn attention to the decomposition of starch in consequence of putrefaction, and proves that starch paste when exposed to the air becomes sour, in consequence of a formation of lactic acid; besides this a considerable quantity of starch-sugar is formed during the process of putrefaction. The starch-sugar, however, is not formed merely from starch alone, but also from fibrin and mucilaginous substances, furthermore from cane-sugar and various other substances.

As early as the year 1835 it was proved that all acids —organic as well as inorganic—will, in a more or less diluted condition, act alike on cane-sugar, by transforming it in a higher temperature, first into glucose or grape-sugar, next into ulmic acid (humic acid), and that by admitting air it turns into formic acid. Small quantities of any diluted acid produce decomposition in the same degree as larger quantities, only slower, according to the degree of their dilution.

This transformation of cane-sugar into grape-sugar is explained thus: The cane-sugar is converted by the

action of the diluted organic and mineral acids—in the first place by sulphuric acid, muriatic acid, etc.—into *intervert sugar*, which latter, according to Dubrunfaut, is a mixture of dextrose (starch-sugar or glycose) and levulose (chylariose or mucilaginous sugar).

$$\underbrace{C_{12}H_{22}O_{11}}_{\text{Cane-sugar.}} + H_2O = \underbrace{C_6H_{12}O_6}_{\text{Dextrose.}} + \underbrace{C_6H_{12}O_6}_{\text{Levulose.}}.$$

Another chemist of repute, *E. M. Raoult*, has even found that cane-sugar, under the influence of light, will be partly converted into grape-sugar.

Physical Properties.—Grape-sugar crystallizes from its aqueous solution in hemispheric warts, or shaped like cauliflower, and absorbs thereby two atoms of water. Its chemical composition in the crystallized condition is therefore expressed thus: $C_{12}H_{24}O_{12}+2H_2O$, or $C_{12}H_{12}O_{12}+2HO$. When heated to 100° C. (212° F.), it melts and ejects the crystal water; the anhydrous grape-sugar thus obtained gradually absorbs again from the moist air all its crystal water.

Glucose, *i. e.*, grape- or starch-sugar, when polarized, turns the rays, like dextrine, strongly towards the right, while fruit-sugar turns them towards the left. The taste of grape-sugar is not as sweet as that of cane-sugar, and it takes two and a half times as much of it as of cane-sugar to sweeten the same volume of water.

Process of Formation. (Explanation of the process occurring by the transformation of starch into glucose and dextrine.)—As regards the process which ensues by the action of diluted acids and diastase on starch, but little is as yet known, and opinions yet greatly vary with regard to this subject. But it has been proven that the acids during this process of trans-

formation of the starch do not suffer any decomposition, and it is moreover an established fact that the efficacy of the diastase is limited, but in what manner glucose and dextrine are formed from starch has not yet been decided. This much is certain, that both glucose and dextrine are the products of transformation produced under the conditions stated. Thus, for many years the opinion was entertained that the starch gum —dextrine—forms mainly as an interim product during the formation of glucose from starch, *i. e.*, under conditions which are favorable to its formation, and is furthermore by the absorption of water transformed into glucose. This erroneous opinion, so generally diffused, was first refuted by *Musculus* in 1861, by producing directly and simultaneously dextrine and starch-sugar as the products of the transformation of starch. Besides this Musculus sought to prove that starch-sugar does not form from the previously obtained dextrine by absorbing more water, but for the most part in a more direct way from the starch. Payen, another authority, was, however, not of this opinion, and furnished by actual experiments the proof that glucose does not merely form from starch, but is also obtained directly from dextrine by boiling it with three per cent. of sulphuric acid, and also by the action of diastase.

The difference of opinion of these leading scholars caused a highly interesting controversy between the two, Payen and Musculus, and thus became the subject of a heated discussion before the Academy of Science in Paris.

From the following extracts from the treatises by Payen and Musculus, a clear perception may be obtained with regard to the processes which take place

during the transformation of starch into grape-sugar and dextrine. We dwell on this subject more minutely for the reason that it will tend better to explain the third part of this treatise—the manufacture of dextrine.

The Transformation of Starch into Grape-sugar and Dextrine according to T. Musculus.—According to the view accepted by men of science—says Musculus—starch is first transformed into dextrine by the influence of the diluted acids, before it is changed into grape-sugar, since dextrine is but a modification of the molecules of starch, and is then transformed into grape-sugar by absorbing four more equivalents of water. By the investigations which I undertook in regard to this subject I have, however, become convinced that the process is a different one, viz., that the formation of dextrine and glucose is rather the result of the decomposition of the starch than of a mere absorbing of water. In order to determine the gradual transformation of the starch into grape-sugar, I used a titrated solution of tartarated potash of oxide of copper, and by means of this reagent I was enabled to pursue the process with accuracy. My opinion with regard to this matter is based upon the following facts:—

a. Diastase has no effect on dextrine. If, for instance, starch is brought together with a diastase solution at a temperature of between 70° and 75° C. (158° and 167° F.), the quantity of the grape-sugar forming increases until the liquid no longer turns red or blue, when testing it with tincture of iodine. At this juncture the transformation ceases, although much dextrine is yet present, a fact easily proved by adding 1 per cent. of sulphuric acid and then boiling it. If now an equal quantity of starch is added, a new trans-

formation ensues, until iodine indicates no further presence of starch, and it is found that the quantity of the sugar formed is doubly increased.

b. Grape-sugar and dextrine appear simultaneously, and are always in the same relative proportion. If the process is interrupted before it is finished, and the unchanged starch is separated by means of filtration, then the filtered liquid, which now no longer turns blue by applying iodine, contains a mixture of dextrine and starch-sugar in solution.

In order to ascertain the quantity of each of these substances, I determined in the first place the amount of starch-sugar by means of the tartarated potash of oxide of copper; thereupon I mixed with the liquid 1 per cent. of the sulphuric acid, placing the same in a strong phial, which, hermetically closed, was brought to boiling for several hours in a strong solution of culinary salt at a temperature of 108° C. (226.4° F.), whereas a mere boiling at common pressure does not suffice in this case. The reaction may be considered under all circumstances as being finished, when the quantity of sugar no longer increases.

I have always found, that after this operation, the quantity of the sugar was three times as large as before. The mixture, therefore, consists of one equivalent of starch-sugar and two equivalents of dextrine; this relative proportion remains the same, whether the influence of the diastase has just commenced or has entirely ceased.

$$\underbrace{3C_6H_{10}O_5}_{\text{Starch.}} + \underbrace{H_2O}_{\text{Water.}} = \underbrace{2C_6H_{10}O_5}_{\text{Dextrine.}} + \underbrace{C_6H_{12}O_6}_{\text{Starch Sugar.}}$$

c. The diluted sulphuric acid operates at first like the diastase; its action, however, differs in so far that

its effect—although weak—continues after transformation of the starch. If starch is boiled with 1 per cent. of sulphuric acid, which has previously been diluted, the quantity of sugar increases rapidly, until the liquid no longer becomes blue by the application of iodine. The solution then contains a mixture of dextrine and grape-sugar in the proportion of 2 : 1, just the same as if the diastase had been applied. By continuing the boiling, the reaction becomes very feeble. When I, for instance, diluted 2 grammes (30.86 grains) of common starch in 200 cubic centimetres (6.75 fluidozs.) of acidulated water, I obtained after a boiling of thirty minutes, and at that juncture when iodine no longer produced a coloring, 0.6 gramme (9.26 grains) sugar, while thereafter an uninterrupted boiling for a period of four hours was required to attain an increase of 30 centigrammes (4.62 grains) of sugar; notwithstanding the fact, that the liquid still contained unchanged dextrine, of whose presence I convinced myself, by exposing the liquid in a closed vessel to a temperature of 100° C. (212° F.). If starch-sugar has hitherto been believed to be a product resulting from the dextrine absorbing more water, it would be unexplainable why its formation ensues more rapidly, while yet unchanged starch is present in the liquid than when merely dextrine is left. Certainly if the above opinion were correct, the very reverse would, as is obvious, be the case.

d. The simultaneous appearance of dextrine and sugar shows itself by the application of sulphuric acid as well as by the diastase, and the proportion in both is the same.

Since, in this case, the starch has become soluble by boiling, it cannot be filtered off, but it must needs be

precipitated with alcohol. It will then have the appearance of resin, precipitated by water from an alcoholic solution. The glucose and dextrine remain in the solution, and can be determined as is stated in paragraph *b*.

From my observations, the following practical applications result:—

1. In the manufacture of starch-sugar, wherever the influence of the sulphuric acid is considered as having ceased, when the liquid no longer is colored blue by iodine, and alcohol no longer produces a white precipitate in the same, a large quantity of dextrine remains mixed with the sugar, and since the same does not ferment with yeast, it will cause great pecuniary loss to the consumer. The manufacturers of glucose must therefore, in order to obtain a good product, apply closed vessels at an increased temperature.

2. The great resistance which the dextrine shows to the action of diluted sulphuric acid furnishes a means for titrating a mixture of cane-sugar and dextrine; and it suffices to boil it one minute, in order to bring all the sugar into a state that the same will react on the tartaric potash of oxide of copper. During this period the dextrine suffers no change whatever. If starch is simultaneously present, it is to be transformed by the diastase, which does not influence the cane-sugar or the dextrine.

3. The large consumption of barley, necessary in breweries, for producing a beverage which does not contain too much alcohol, finds its explanation in the mode of operating of the diastase; two-thirds of the starch passes over into the beer as dextrine, whereby the beer receives a somewhat gummy consistency, which is rather in its favor.

4. In the distilling of brandies and whiskeys of grain, wherever the sugar is produced by germinated barley (malt), two-thirds of the same is unavoidably lost.

Thus far Musculus. The following essay shows Payen's opinion on the subject.

Production of dextrine and starch-sugar by the action of sulphuric acid or muriatic acid; by means of diastase or diastase and yeast combined. Extracting the wood-fibre from the wood. Manufacture of mucilaginous sugar by means of malt or sulphuric acid, by Anselm Payen.— By reading the report which *Chevreul* submitted to the French Academy of Science respecting the history of the essays treating on starch, it will be perceived that, since 1716, numerous chemists have devoted themselves to the investigation of this matter. But, notwithstanding all this, this highly interesting subject is even, despite all the researches made of late, not yet thoroughly exhausted. Thus, for instance, neither the savants nor the manufacturers, who of late were active in the investigation of the transformation of starch into dextrine and glucose, had any direct test for determining the relative quantity of the two substances produced, when the same were worked under certain conditions of time and modes of operation.

Biot, however, was the first who, by means of the optical method created by him, observed the progressing trans- and sugar formation. It has generally been accepted, that the first stage of the process furnishes the maximum of dextrine and the minimum of sugar, and that the latter increases with the continuance of the action. But no endeavor was made to fix the most favorable conditions for this transformation, or to ascertain the limits of the same for the various agents. When, in a report recently made

to the Academy, it was stated that the proportion of 2 : 1 was the right one which existed between the constant quantities of dextrine and sugar, which have formed simultaneously at the expense of the starch by the intervention of water and diastase, or by sulphuric acid, it was at the same time shown that the production of a greater quantity of sugar by the diastase was impossible, and by means of sulphuric acid so difficult, that we were inclined to view the production of the two substances rather in the light of being a decomposition, than a mere increased absorption of water on the part of the starch substance. This of course tended towards the proposal of making a considerable change in the usual method of manufacturing glucose by sulphuric acid. This experience led more especially to the application of closed vessels, and to recommending an increase of the temperature or pressure to 108° C. (226.4° F.). The action of the diastase on starch was considered as being incapable of transforming more than one-third part of the same into sugar, while the two remaining thirds seemed to withstand all the further formation of sugar by the same means. It was, for instance, thought that in the distilling of brandies from grain or corn, where "generated" barley (malt) produces the fermentable sugar, an unavoidable loss of two-thirds of the alcoholic product had been suffered.

When I learned of these interesting observations—said Payen—the theoretical conclusions did not appear to me to be justified. If it is moreover considered, that those parts of the grain containing starch possess a very varying aggregate in the single grains, and, in the ten to fifteen single concentric layers which form each grain, show alternately a maximum and a minimum of

power of cohesion, running from the exterior towards the interior, it may be considered as probable that this different condition not only produces many noteworthy phenomena, which have already been alluded to by me some time ago, but it also tends to explain the rapid change of the starch into two different products; the one resulting from the dissolution, and almost immediate formation of sugar, while the other corresponds with the cessation after the difficult dissolution of the denser parts. It seems furthermore probable, that this resistance may be increased by the presence of the already formed sugar, and that it may be possible to remove these obstacles either partly by prolonging the influence, or still more completely by the removal of the sugar by means of fermentation. This latter opinion was based on an attentive study of the general appearances displayed during the chemical process. I have made these observations by the aid and co-operation of the renowned chemist *Billevuin*, of Paris. The results derived therefrom, and which are based on the application of accurate tests of the various products obtained by the action of diastase and acids on starch and dextrine, as also those which relate to the double action of the diastase and yeast, are meantime in nowise in contradiction with the "*Manual*" which I published in 1843, or with those facts which I have promulgated since. Hence, all the statements with regard to the various forms, sizes, and structures of the starch in the different plants, and regarding their various contents of water, and the different amount of cohesion in the same starch-granules, or which relate to the age of these granules as well as to the manner of their solution, and their penetrating through the texture during the life process, and finally to the occa-

sional return of the same to their original state and structure, all these phenomena remain unaltered and correct.

On the other hand, all these later experimental investigations extend more particularly to the numerical determination of the transformation products as they form under various conditions;—I mean both during the converting of the starch into dextrine and sugar, as well as during the conversion of the dextrine itself into starch-sugar.

It had been my intention either to substantiate the observations communicated by Musculus, or to set forth new facts, which may serve as an explanation of many processes in the field of industry and agriculture.

a. The first of the mentioned series of observations leads to the finding out of those conditions by which we will be enabled to obtain in a direct way from 51 to 83.6 per cent. of starch-sugar ($C_{12}H_{12}O_{12}$) from the starch substance, by means of a 3 per cent. sulphuric acid; without increasing the temperature of the liquid above the boiling point, without varying the quantity of water or acid, and without causing the total duration of action to last longer than from three and one-half to five hours. Hence, it is clear that the starch and thereupon the greater quantity of the dextrine is gradually transformed into sugar, and consequently it is not necessary to work closed vessels in order to transform the starch into so much sugar that the same by gradual crystallization congeals into a solid substance.

b. A direct experiment has proven that the dextrine of commerce, under similar conditions, will furnish a product of 84 per cent. starch-sugar.

c. Another series of experiments proves that muriatic

acid acts yet somewhat more powerfully. With equal equivalents and according to the method of operation it furnishes of starch a product which contains 62½ to 85½ per cent. pure starch-sugar.

d. If muriatic acid is permitted to act under similar conditions, but for a longer period of time upon wood fibre, then we obtain from the less firm fibrous substance and from an incrusting substance similar to the same, in the first place dextrine, and then fermentable sugar, while the denser fibrous substance remains unchanged. By this manner two different products may finally be obtained, viz.: alcohol which is easily distilled off, and fibrin sufficiently solid to be applicable for the manufacture of paper. From beech-wood, pine-wood, poplar-wood, and the straw of cereals, from 10 to 15 per cent. of alcohol can be thus obtained, and also 25 to 30 per cent. of pure dry cellular substance.

e. During the action of diastase on starch, by fractioning it off four times within the space of two and one-half hours, showed steadily increasing amounts of sugar, thus: 17.9 per cent., 20.97 per cent., 25.89 per cent., and finally 26.03 per cent. of the dry substance originally used. Thus the dextrine formed after the liquefying of the starch changes gradually into starch-sugar, until the further transformation is stopped by the forming of too large a quantity of sugar.

It is indeed possible, that after all the sugar has been removed by fermentation, to again introduce the formation of sugar from the dextrine by further application of the diastase, and realizing the same amount of sugar as previously. Since similar products have been obtained by the action of diastase on commercial dextrine, it is indeed proved, that the diastase will actually transform the dextrine into sugar.

f. A further series of experiments has proved that brewer's yeast is unable to cause dextrine to ferment; but by the united action of diastase and the yeast, the starch is in the first place transformed into dextrine and sugar, and the latter into alcohol and carbonic acid gas. Thus, it is now entirely clear, that by following the directions given by me (Payen), the almost total transformation of the starch into alcohol will be accomplished.

These new investigations furnish the key for obtaining by wise management a better result in distilling liquor from grain or brewing beer from malt. They furnish the conditions which must be observed, if the maximum yield shall be obtained, and they also explain the remarkable inconformities which sometimes occur in the pursuit of these operations as carried on in large manufacturing establishments.

g. In another series of experiments the starch was mixed with warm water and by an addition of more water changed into thin paste, and thereupon subjected to the influence of the diastase at certain different temperatures. Thus as high as 52.7 per cent. of the raw starch was transformed into starch-sugar. If, therefore, none of my (Payen's) numerous experiments was able to produce by direct sugar formation by means of diastase a higher percentage of sugar than that given by the above figure, how could the figure of 87.1 per cent., as given by another experimentator (Musculus), ever have been attained?

h. But even if the maximum transformation of sugar is reached, the syrup obtained from the dextrine and sugar will not be directly crystallizable.

i. In the same manner a limited result was only obtained when I endeavored to effect the transformation

of starch into dextrine without the formation of sugar by 85° C. (185° F.). Near the limit, where the efficacy of the diastase ceases, the two products of this special reaction are yet forming under its influence, and no exception to the general rule does therefore take place.

If, however, the diastase operates yet upon the paste at 85° C. (185° F.) so does this occur only because it has not been previously brought up in its aqueous solution to this temperature, since if this had been done, the actual limit of its efficacy would sink to 80° C. (176° F.).

k. It is a noteworthy phenomenon also observed by me (Payen), that the diastase still manifests its effect at temperatures below 0° C. (32° F.), but under these circumstances not merely dextrine is formed, as has been alleged by Musculus, but I found also upwards to 38.2 per cent. of sugar in the product. Hence, here too, no exception to the general rule takes place.

l. The clear, thick syrups, almost without color, and without a tendency to crystallize, as they are now manufactured and offered in commerce as "imponderable syrups" made of wheat, maize, or malt, are produced from the starch of potatoes or corn by means of about .007 of their weight of sulphuric acid. One of the finest samples contained but 11.1 per cent. of water, and for each 100 parts of dry substance used 47.73 starch-sugar. By applying these syrups in lieu of the dextrine syrups made from starch and diastase, the labors of the manufacturer have doubtless been lessened. Besides this, the peculiar malty taste has been avoided; but in doing it neither as pure a taste of sugar nor as much mucilaginous substance is obtained, which recommends the syrups of dextrines for medicinal purposes; nor were those advantages attained,

which the latter syrups made of malt and starch afford to the beer brewer.

The small quantity of .007 sulphuric acid is ample to furnish by our previously-mentioned process a syrup whose amount of sugar will be 69 per cent. of the material used, and it may be done in an open vessel.

m. Although but little acid is used nevertheless a certain quantity, however small, of sulphuric acid and gypsum will always remain in the syrup obtained, which cannot even be entirely removed by filtration through a thick layer of coarse-grained animal charcoal.

Meantime the contents of gypsum are much less in these non-crystallizing syrups than in those of 33° B., or in the crystalline congealed starch-sugar of 40° B. This fact tends to show that in the art of beer brewing, these products should be substituted by syrups produced by means of diastase. Such a change would, beyond doubt, be of the greatest advantage to the wholesome properties of this beverage.

Recent Improvements in the transformation of Starch into Dextrine and Sugar.—In a treatise, submitted to the French Academy of Science by Musculus, the following points of his controversy are noteworthy:—

"Payen believes that I (Musculus) have been misled by the peculiar structure of the starch granules, inasmuch as I could accidentally have found a mixture of sugar and dextrine, in consequence of the greater or smaller aggregation of the individual layers of the granules. But it is the fundamental experiment, communicated by me in my previous treatise, which has led me to an entirely different opinion from that so generally accepted, leaving entirely out of consideration the structure of the starch granules.

The test is as follows:—

When starch is treated in a solution of diastase, and the gradual forming of sugar is determined from time to time, it will be found that the quantity of the sugar, until the transformation of the starch is complete, steadily increases—which may be easily perceived by testing with a solution of iodine. After this point is reached no more sugar will be formed however long the heating may be continued, although some unchanged dextrine remains in solution, as Payen himself has found. But whenever a new quantity of starch is added the formation of sugar again begins to cease as soon as the starch is converted, and so on until the efficiency of the diastase is exhausted, *i. e.*, when according to *Persoz* and *Payen* 1 part of the diastase has dissolved 2000 parts of starch. How can this phenomenon be explained if we suppose that starch in the first place is transformed into dextrine and then into sugar? In this case we must needs suppose that the diastase would act with a stronger effect upon one part of the dextrine than upon the other, which of course is impossible.

If the starch is treated with diluted sulphuric acid instead of diastase, the same process of transformation takes place, but the formation of sugar still progresses even then—although very slowly—when the starch has become entirely decomposed. This also has been acknowledged by Payen, since he had to keep up the heating for five hours in order to obtain the maximum yield of sugar. Since this operation progresses faster by an increased than by a normal pressure, I suggested to bring about the transformation of starch into sugar in closed vessels; hoping by this method to work less expensively and to attain a less colored product; it

being a well-known fact, that a solution of sugar by continued boiling becomes brown. If to the mixture, already boiled by an increased pressure, fresh starch be added, the formation of the sugar is greatly accelerated, and the liquor thus obtained—when the starch has been worked in the form of thin paste—will no longer react blue with tincture of iodine after boiling about thirty minutes.

When, as already stated, the constant quantities of dextrine and sugar, which are formed by this process, stand in the proportion of 2 : 1, I desired to designate only those quantities which originated from the direct decomposition of the starch. It is, therefore, not remarkable that Payen does not agree with me, although in order to find this proportion, I interrupted the operation at the moment when the tincture of iodine indicated the disappearance of the starch, while Payen continued the heating until the entire cessation of the formation of sugar.

Meanwhile the conformity is again established when the experiment of Payen *ad e* is compared with that of *ad a*. By the experiment *ad e*, Payen obtained by the action of the diastase 26.03 per cent. of sugar, but by the experiment *ad a*, whereby he exhausted the effect of the sulphuric acid (which had been added in the proportion of 3 per cent.), he reached 83.6 per cent. sugar, which approaches the ratio as specified by me. It becomes manifest that by Payen's experiment *ad e*, the diastase merely transformed the starch into sugar, while by the experiment *ad a*, by means of the continuous action of the sulphuric acid, sugar was formed directly from starch as well as from dextrine.

Payen states, that another experiment with diastase and starch resulted in a gain of starch-sugar of up-

wards of 50 per cent., when he caused the diastase to act upon paste; an amount which I (Musculus) could never reach, even when I continued the heating for twenty-four hours more, after the starch had disappeared. This result would prove that the starch-sugar would only incompletely balance the effect of the diastase on the dextrine, and thus the mode of operation of the diastase and that of the diluted sulphuric acid would be shown as more nearly similar. But if starch-sugar prevents the further formation of sugar from dextrine more or less, it does not prevent its formation from starch direct, whence it follows, that as long as starch is contained in the liquid, the dextrine will not be acted upon.

And finally Payen found that the action of the diastase takes place somewhere near —10° C. (14° F.), and that at this low temperature as well as at some higher, a mixture of sugar and dextrine is always created. Never yet has dextrine been obtained without some sugar. I believe that this result may be considered as a confirmation of my statements.

On the Effect of Diastase on Starch under various conditions.—A. Payen, in reply to the above treatise of Musculus says: Musculus' pamphlet contains the following three concluding results, viz:—

1. The diastase does not act on the dextrine.

2. The diastase always produces by its action starch-sugar and dextrine in the same proportion, to wit, one part sugar and two parts dextrine.

3. In the distillation of spirits from grain, whereby the formation of sugar is effected by means of germinating barley, an unavoidable loss of two-thirds of the latter takes place.

These three conclusions are not admissible. They

are in contradiction to the established results of several older investigators on starch, but more especially to the results of my own experimental tests.

I have resumed these investigations, and have been successful in ascertaining the causes of the different results, and am able to prove with accuracy:—

1. That the diastase operates on the dextrine, and can partially pass the same over into sugar.

2. That the diastase, while operating on the starch, can produce dextrine and sugar in different proportions, according to circumstances, and within the limits of 17 to 50 per cent., and even more of sugar can be realized from the entire product.

3. That in the manufacture of high wines from grain the entire quantity of starch, excepting but a small percentage, can be gradually changed into sugar and alcohol.

After having established the latter point experimentally, I have for several years followed up these results, and proved them on a larger scale by some of the ablest distillers of grain spirits. With regard to the first point, I have proved the action of the diastase on dextrine, by using dextrine obtained by two different methods of manufacture.

The one kind of dextrine was pulverized, and was such as is made in the manufactories by the action of a very small quantity (0.005 gramme, 0.077 grain) of muriatic acid upon starch at a temperature of 120° C. (248° F.). The solution of this dextrine was neutralized with carbonate of ammonia, and thereupon treated with a solution of diastase for a period of four and a half hours at 70° C. (158° F.), after which the 250 cubic centimetres (8.44 fluidounces) liquid, being the pro-

duct of 20 grammes (308.6 grains) dextrine, contained 5.065 grammes (78.16 grains) of sugar, viz.:—

For 100 grammes (3.5 ozs. avoir.) dextrine sugar	25.235
Deduct therefrom the original amount . .	5.23
The product of the sugar formation by means of the diastase amounted to . . .	20.005

The other dextrine was obtained by removing all sugar from a liquor which had been prepared by the action of the diastase on starch. The sugar was in this case removed by fermentation. The solution of this dextrine was evaporated until dry, the residuum weighed and again dissolved in water, then exposed to the action of the diastase at a temperature of 75° C. (167° F.). From an amount of 4.3 grammes (66.3 grains) dextrine used, were obtained 1.154 grammes (17.8 grains) of sugar, or 26.8 per cent. sugar for each 100 of dextrine. By this it has been proven, that the dextrine by the diastase is partly transformed into sugar. Furthermore, from this fact the conclusion can be drawn, that the further formation of sugar is prevented by the presence of sugar, since after the removal of the latter the diastase has again manifested its former power to form sugar. And beside all this we may conclude, that, during the alcoholic fermentation of this mixture of diastase with various quantities of starch, dextrine, and sugar, the real obstacle disappears in the same ratio as the sugar changes into alcohol and other products, and the diastase in consequence thereof regains its efficacy.

In the first place, two experiments proved, that the alcoholic fermentation alone (after the action of the

diastase was stopped by boiling) is unable to change dextrine into sugar. A third experiment was made, with the intention of effecting the fermentation of that substance which had been converted into sugar by the diastase, and at the same time not to weaken the strength of the diastase. 100 grammes (3.5 ozs. avoir.) of starch were boiled into paste in 1 litre (2.1 pints) of water, the temperature lowered to 25° C. (77° F.), and thereupon by the application of malt a liquor was produced within the period of two hours, which, after filtering, contained 6.72 per cent. of dry substance, wherein were contained 41 per cent. of sugar and 59 per cent. of dextrine. The rest of the liquid which was not filtered we allowed to ferment with yeast, for eleven days, which caused one part of the paste to become liquid. 100 grammes (3.5 ozs. avoir.) of the filtered solution contained 2.5644 grammes (39.57 grains) of alcohol; while the 2.76 grammes (42.58 grains) of sugar, which had been present before the fermentation, corresponded only with 1.41 grammes (21.76 grains) of alcohol. The surplus found, *i. e.*, 1.56 grammes (24.07 grains) of alcohol, corresponds at least to 2.261 grammes (34.89 grains) sugar, which were produced by the action of the diastase on the dextrine, in the same ratio as the obstacle to this transformation disappeared. The formation of sugar, therefore, had, in consequence of its continuation during the alcoholic fermentation, almost doubled its original amount by its action on the dextrine. Even 6 per cent. more of the same might be found, if the subsidiary products were brought into account. It is therefore obvious that distillers, instead of unavoidably losing at least two-thirds of the substance which passes into alcohol and sugar, will, by careful manipulation, rather

reach within a small percentage of the production which is theoretically possible.

Thus it remained yet merely to investigate whether diastase by its action on starch does always produce sugar and dextrine in the proportion of 1 : 2. We will see that this proportion, according to circumstances, may greatly vary.

A series of experiments, in which a mixture of 100 grammes (3.5 ozs. avoir.) of starch were heated to 75° C. (167° F.) with 15 grammes (231.45 grains) pulverized malt and 1000 grammes (35 ozs. avoir.) of water in a water-bath, furnished the following proportions:—

	After 20 minutes.	After 28 minutes.	After 78 minutes.
Sugar	17.9	20.97	25.83
Dextrine . . .	82.1	79.03	74.17

After the process had been so modified that the action of the diastase on the previously watery and partly dissolved starch was quickened, the transformation of the latter furnished a larger proportion of sugar and a smaller proportion of dextrine.

Into a paste of 20 grammes (308.6 grains) starch, and 200 grammes (7 ozs. avoir.) of water, which was brought to 75° C. (167° F.) and kept at that temperature, 20 grammes (308.60 grains) of malt were quickly stirred, and in the dry substance of the evaporated liquid were found—

	After 2 hours.	After 22 hours at 50° C. (122° F.)
Dextrine	58.94	57.37
Sugar	41.06	42.63

In order to be brief I will abstain from a more elaborate explanation of three experiments which furnished 43.17, 43.16, and 43.36 per cent. starch-sugar, but I

will state the conditions by which I succeeded in carrying on the formation of sugar still further:—

50 grammes (1.75 ozs. avoir.) of starch were mixed with 400 cubic centimetres (13.5 fluidounces) of water having a temperature of 100° C. (212° F.), while constantly stirring, and thus a temperature of about 92° C. (197.6° F.) was obtained; thereupon the temperature was allowed to run down to 25° C. (77° F.), and 7.5 grammes (115.72 grains) of malt were stirred in, and the temperature kept at 25° C. (77° F.), while an occasional stirring of the mixture took place.

The dry substance of the solution contained—

	After 4 hours.	After 6 hours.
Dextrine	55.17	52.14
Starch-sugar	44.83	47.86
	100.00	100.00

Another experiment, in which the temperature was maintained during two hours and forty-five minutes at 40° C. (104° F.), furnished 100 parts of dry substance, of which 49.33 per cent. were sugar and 50.67 per cent. dextrine.

Notwithstanding this, the maximum of sugar to be obtained by the action of the diastase had not been reached. Two further experiments, the one at a constant temperature of 50° C. (122° F.), the other at 40° C. (104° F.), and each experiment being divided by two periods, proved that the formation of sugar still continues for a short time after the complete liquefying, and that the maximum of sugar may amount to more than 50 per cent. of the entire product.

	1st exp. at 50° C. (122° F.)		2d exp. at 40° C. (104° F.)	
	After 4 hours.	After 6 hours.	After 2½ hours.	After 4½ hours.
Dextrine	53.4	50.099	52.876	48.05
Starch-sugar	46.6	49.901	47.124	51.95
	100.0	100.000	100.000	100.00

The maximum of sugar which may be directly obtained may therefore greatly exceed the limits of 33 per cent., a fact not deemed possible by Musculus.

Final results:—

1. By the action of diastase upon dextrine, sugar is formed.
2. The action thereof suffers an interruption by the presence of starch-sugar, but is re-established when the sugar is removed.
3. When the starch-sugar is transformed by fermentation into alcohol, and thereby the formation of sugar from dextrine is no longer impeded, the action of the diastase returns, and thus, instead of losing 66 per cent. (according to Musculus) of the starch-containing substances in the manufacture of spirituous liquors, the entire quantity of the starch is gradually transformed, excepting but a small percentage, into sugar, alcohol, and subordinate products.
4. If the diastase is caused to act upon the starch under favorably arranged circumstances, not only more than 33 per cent. of sugar, but even more than 50 per cent. of the same, can be obtained.

Annotations to Payen's Essay, by G. C. Habich.— The renowned technician Habich submits the follow-

ing interesting notes respecting Payen's assertion, ad 4:—

It is an indisputable fact that the dextrine contained in our concentrated extracts of malt does ferment, or plainer told, does get transformed into grape-sugar during the second fermentation.

Notwithstanding this, Payen has endeavored to prove by his experiments that this fact is a myth. He has tried to show by two experiments that the alcoholic fermentation alone (after removing the action of the diastase by boiling) will not change dextrine into sugar. The sense of this sentence, according to how much importance is attached to these unknown experiments, may be expressed by the two following sentences:—

1. After the quantity of sugar, which was known as a maximum obtained by the mash-process, had been decomposed, no further formation of alcohol took place.

2. The amount of dextrine fixed prior to the fermentation was found, after the fermentation, to be undiminished.

We will furnish the proof, that Payen could not possibly have obtained the above results. In order to make the position of Payen as advantageous as possible, we will investigate the experiment relating to the largest yield of sugar (to wit, second experiment at 40° C.) (104° F.), by which 48 per cent. dextrine and 52 per cent. sugar were obtained. The extract of malt and hops contains, however, yet other substances besides sugar and dextrine. *Reischauer*, for instance, found in a malt- and hop-extract 42.6 sugar, 52.3 dextrine, and 5.1 other ingredients (albumen, alkalies, resin, etc.). In the proportion found by Payen of 52 per cent. sugar and 48 per cent. dextrine, the compo-

sition of the above beer-malt extract would appear thus:—

49.3 per cent. sugar,
45.6 " dextrine, and
5.1 " other ingredients.

If the dextrine does not join in the fermentation, then we obtain after the fermentation (whereby from 100 parts glucose 51.11 parts of alcohol are produced, and 5.619 parts of yeast are separated)—

From	49.3	per cent.	sugar . .	25.2 alcohol.
"	45.6	"	dextrine . .	45.6 dextrine.
"	5.1	"	other ingredients	2.9 residue.

Let us now compare with this the composition of a well, but by no means yet in its fermentation, finished beer. We find, for example, that the so-called "*Hofbrauhausbeer*" in *Munich* contains 4.06 per cent. of alcohol and 5.55 per cent. of extractive substance; the so-called "*St. Marx beer*," of Vienna, 5.75 per cent. alcohol, and 6.54 per cent. extractive substance. The still better fermented Dutch beers furnish yet less extractive substance.

And now if we consider that, according to Payen, the proportion of alcohol to dextrine in the finished fermented beer must be as 1 to 1.92, then all that it missed must needs belong to the impossibilities.

These facts furnish ample proof, that Payen's doctrine, that the dextrine cannot be "decomposed" or transformed during fermentation, is incorrect.

It is of course correct, that all dextrine is never transformed by the process of fermentation; but that a very considerable part of the dextrine is transformed by the fermentation into alcohol, can hardly be doubted, after what has already been stated.

On the Transformation of Starch into Sugar by means of Malt, by Dubrunfaut.—Dubrunfaut has submitted to the French Academy of Sciences, an interesting essay, entitled "On the effect of malt on starch."

1. One part of malt which, at the temperature of 70° C. (158° F.), has no noticeable action on 1000 parts of starch, is capable of completely liquefying the same quantity of starch when the process is commenced at 50° C. (122° F.) or below this temperature. In this case, a complete solution ensues, but the formation of sugar remains incomplete. If the process takes place at a temperature of 25° to 30° C. (77° to 86° F.), then the liquefying is less complete and less rapid, while the formation of sugar is stronger and more perfect.

2. If starch-paste is mixed at 50° C. (122° F.), or even at a lower temperature, with 1 part of malt, this will be ample to change 100 parts of starch as completely into sugar as 20 to 25 parts of malt do at 70° C. (158° F.).

3. One part of malt will liquefy 100 parts of starch at a temperature of 70° C. (158° F.), within nine minutes; but in this temperature the formation of sugar cannot take place completely, since the malt in that case can only produce three-quarters of the result which can be attained under the most favorable conditions. The same quantity of malt causes the same quantity of starch at 50° C. (122° F.) to become liquid within twenty-five minutes, while, at a temperature of from 25° to 35° C. (77° to 95° F.), the solution becomes complete only in the course of two or three hours. In the two latter cases, however, a perfect formation of sugar ensues. Of course the time required for this varies. At 30° C. (86° F.), it ensues less rapidly than at 50° C. (122° F.), but without noticeable

difference, as to the completeness of the formation of sugar.

4. If the formation of sugar is produced by a quantity of malt which, in comparison to that of the starch, is but very small, then the final result will be the more complete, the lower the temperature which has prevailed at the trial, while the same small amount of malt would, at a temperature of between 53°.7 and 64°.4 C. (128° and 148° F.), have no effect at all, as is for instance the case by the application of 0.001 part of malt. In such cases a larger or smaller quantity of starch frequently resists the action of the malt entirely, *i. e.*, this part does not even become liquefied, and still less converted into sugar. But in general this result is found by otherwise equal conditions to a large extent, occasioned principally by too small a quantity of water taken for conversion. If, for instance, to a paste prepared of 1 part starch and 20 parts water, is added, at 40° C. (104° F.) or at a still lower temperature, 0.01 malt, one-seventh to one-sixth of the paste will entirely resist the transformation. Thereby the remarkable phenomenon appears, that this unchanged starch-paste, even if it is brought in contact, under the most favorable conditions, with larger quantities of malt, can neither be caused to become liquefied, nor made saccharíferous, while it is still affected by acids, and by them partly transformed into sugar. According to this, the starch has by these conditions undergone a modification. Such a starch-paste contains more azotic than normal starch. Starch at 70° C. (158° F.), mixed into a paste with fifty times its weight of distilled water, does not become liquid, even when the paste is exposed for several days to the influence of a temperature of 50° C. (122° F.).

Cold prepared extracts of raw barley, wheat, and rye liquefy and saccharify starch-paste at 50° C. (122° F.) completely, while in a temperature of 70° C. (158° F.), they remain without producing an effect.

Deductions.

If we now sum up the different opinions, as set forth by Payen, Musculus, Dubrunfaut, etc., with regard to the formation of dextrine, and the transformation of starch into starch-sugar and dextrine, we will come to the conclusion—

1. That starch, by being torrefied in a temperature not exceeding 180° to 200° C. (356° to 392° F.), is in a preponderating degree transformed into dextrine.

2. If the starch is heated with diluted acids, it changes in the first place into soluble starch, which is then transformed into starch-sugar and dextrine. The quantity of the sugar forming depends on the concentration of the acids, and increases during the period of its action considerably, while, as will be obvious, the amount of the dextrine at the same time decreases.

3. If the starch is heated with a solution of diastase (extract of malt), it will likewise at first change into soluble starch, of which thereupon the larger part is first turned into dextrine and a lesser part into sugar. The quantity of the forming starch-sugar will depend above all on the temperature under which the diastase operates. A larger quantity of sugar is formed at a temperature of from 60° to 65° C. (140° to 149° F.), this being the most suitable temperature for the formation of sugar, but at increased temperatures, say at 65° to 75° C. (149° to 167° F.), larger quantities of dextrine

are formed, until finally, by a continued increase of temperature, the diastase itself is destroyed.

The sugar formation increases during the action, by the diminution of the dextrine, especially when the sugar formed is caused to ferment by yeast, and is thereby removed. The quantity of the formed sugar exceeds, even in the most favorable cases, the amount of the dextrine but little.

Chemical Properties. Action. Decomposition.

Mitscherlich had already promulgated the doctrine, that starch-sugar as well as fruit-sugar by fermentation changes at once into alcohol and carbonic acid, without previously passing through an intermediate state. This opinion has been verified and sustained by chemists of a later period. Cane-sugar, on the other hand, cannot be fermented immediately; it must first pass into the condition of starch-sugar before it can undergo the process of alcoholic fermentation. But it is not necessary for the cane-sugar to be previously entirely transformed into starch-sugar; but this transformation takes place very gradually, and in the same ratio as fermentation itself progresses.

When cane-sugar and starch-sugar are simultaneously exposed to the action of yeast, the fermentation of the grape-sugar ensues very soon at 20° C. (68° F.); while in the solution of cane-sugar, even after the lapse of a month, no alcoholic formation is noticed even if the temperature is increased to 25° or 40° C. (77° or 104° F.). Only by increasing the amount of yeast sixfold (to 9.42 grammes for 35 grammes of sugar = 145.35 grains for 540 grains of sugar) does the fer-

mentation begin at last, and then but slowly, because the transformation of the cane-sugar into starch-sugar has been, so to say, forced by the large quantity of yeast. The further assertion of later chemists, that to the cane-sugar need only be added some cream of tartar, in order to facilitate the process of fermentation, is entirely confirmed. Of course this occurs in consequence of its transformation into starch-sugar. We can, therefore, in general state that cane-sugar in its unaltered condition is not fermentable, but will easily change into direct fermentable starch-sugar and also into fruit-sugar, since the mere contact with yeast, or the heating with a few drops of muriatic acid suffices for this purpose.

The solutions of grape-sugar are decomposed by the action of the yeast; the sugar separates and furnishes the usual products of the alcoholic fermentation, *i. e.*, alcohol and carbonic acid, besides some other, less important products.

Grape-sugar is more soluble in alcohol than cane-sugar, since 100 weight parts of absolute alcohol will dissolve 1.66 weight parts of grape-sugar completely (alcohol of 83 per cent. dissolves 18 parts of starch-sugar). But in water grape-sugar is less soluble than cane-sugar, and requires for its solution $1\frac{1}{3}$ parts of its weight of cold water. In boiling water it is soluble in all conditions, and forms a sweet syrup which, however, cannot be drawn into threads like the syrup of cane-sugar.

By increasing the heat from 200° to 220° C. (392° to 428° F.) the starch-sugar is changed into *glucosan* or *caramel*, and other products of a brown color.

Chemical Combinations.

Starch-sugar is dissolved by concentrated sulphuric acid and with it forms a double acid: *Starch-sugar-sulphuric acid*, which furnishes, combined with lime and barium, soluble salts. If grape-sugar is continuously boiled with diluted sulphuric acid or with muriatic acid, it is changed gradually, *i. e.*, is decomposed, and the product is no longer fermentable.

Starch-sugar enters into combinations with alkalies and alkaline earths, which however are not very constant, even at a common temperature, but very readily become decomposed. This decomposition ensues almost instantly at an increased temperature, and the solutions of these salts are colored at a temperature of 70° C. (158° F.) yellowish-brown, and at the boiling point, with admission of the atmosphere, black. This is caused by the formation of an organic acid (glucic acid) produced by the action of the alkalies on the sugar.

Another chemical combination ensues of starch-sugar and hydrate oxide of copper, which is demonstrated by Fehling's alkaline solution of copper, and its action on grape-sugar, which we use to determine the quantitative proportion of grape-sugar. This combination forms a precipitate, which, being dried in the air, forms a bluish-green powder, partly soluble in alkali. When the proportions are accurately observed, the filtered liquid contains neither grape-sugar nor copper.

For practical purposes, the most important of all the chemical compounds grape-sugar forms is that with chloride of sodium (culinary salt), forming thus the so-called chloride of sodium glucose.

This chemical combination, so very suitably employed for preserving various articles of food (meat, butter, milk, wine, beer, and vegetables), we will elucidate more fully in the course of this treatise.

SECTION II.

THE TECHNOLOGY OF STARCH-SUGAR.

The Manufacture of Starch-Sugar.

General Introduction.—It has already been stated that grape-sugar, as well as grape-sugar syrup, commonly called glucose—whose manufacture somewhat later had been recommended by the application of malt, after a clearer idea had been attained of the process of the sugar formation by means of diastase—for a long time failed to enjoy the desired development. The syrup of starch-sugar then only attracted the merited attention, when the want of the East India syrup made itself felt in Europe, as a consequence of the propagation of the manufacture of beet-sugar. The beet-sugar manufactories or refining establishments furnish, as is known, an article similar to the East India loaf-sugar, but they fail to furnish a syrup which is identical with that from the East Indies. For this reason glucose was commenced to be manufactured in large quantities, partly as a substitute for the India syrup, and partly for an admixture with the East India product, and thus to cover the deficiency of this syrup. In this country the admixture of glucose with cane-syrup is principally done to improve the color and body of the latter. The solid starch-sugar, too, found afterwards the merited consideration; again, in order to bring up the quantity of sugar in the grape-juice (*must*) of a poor wine year, and

for reducing (gallesizing*) the contents of acid, and also for the purpose of increasing the quantity of wine correspondingly (petiotizing†). For the preparation of other wines (fruit-wines), and for the distillation of brandies from fermented liquors, starch-sugar is likewise used, and also in considerable quantities for the production of "sugar-couleur."

Grape-sugar finds no application, which common sugar (crystallizing sugar) could not supply; starch-sugar must always be considered as being a substitute for crystallizing sugar. Hence it follows, that the manufacture of starch-sugar is only advantageous when it can be produced more cheaply than cane-sugar or beet-sugar. Besides the price of the crystallized sugar that of the starch, or what amounts to the same the value of the starch-containing materials, is a matter of first consideration. When we consider that the article represented in commerce as starch-sugar is very often far from being pure grape-sugar, containing upwards of 50 per cent. water and substances which are not fermentable, we are led to believe that starch-sugar is more used than is profitable, and would advise the consideration not merely of the price of the article, but also of its quality.

The transformation of starch into sugar by means of sulphuric acid and diastase (malt) has already been explained in a former chapter. If starch is boiled in water containing sulphuric acid, there will be produced from the starch, in the first place, soluble starch

* *Gall*, a celebrated chemist, has made himself meritorious by improving wine by this process; hence it is named, after him, the "Gallesizing" process.

† To increase the quantity of wine by this means was recommended by *Petiot*, and hence this method is called "*petiotizing*."

(*amidulin*); from this is formed by continued boiling, starch-gum (dextrine-gum) and starch-sugar (glucose), and if the boiling is continued sufficiently long, an almost complete transformation of gum into sugar takes place, *i. e.*, the liquid contains besides the sulphuric acid (which remains unchanged) almost nothing else but starch-sugar.

The process of transformation can be followed up by means of a solution of iodine and by alcohol. The liquid will prove to contain no more soluble starch, nor any of the above-mentioned intermediate products, as soon as a cooled-off sample thereof is no longer colored reddish or blue by applying a solution of iodine. When this point is reached the liquid will, when mixed with a larger quantity of alcohol, precipitate a white mass of dextrine. By still continuing the boiling, the quantity of the precipitate decreases, until, at last, by a test with alcohol, no further precipitation ensues. Formerly it was accepted that, at this juncture all starch-gum had been transformed into sugar, and that the liquid then contained naught but starch-sugar. But according to *Anthon*, an authority on this subject, this is not the case. The presence of a larger quantity of sugar besides the gum, either prevents the precipitation of the latter by alcohol, or an intermediate product is formed, which is not precipitated by it.

Starch-gum (dextrine) is indissoluble in alcohol, and is by absolute alcohol precipitated from its aqueous solution. The complete transformation of starch into sugar cannot be determined with certainty by alcohol. The non-observance of this fact is the cause of the grape-sugar of commerce being frequently far from pure sugar. Only by dint of long-continued boiling is

the object effected of having the liquid contain almost nothing else but starch-sugar.

The relative quantity of sulphuric acid used is of importance, as the duration of time for a conversion is dependent upon it.

The transformation occurs, for instance, much more rapidly when two per cent. of sulphuric acid is added to the starch than when but one per cent. acid is applied. By the boiling with an increased pressure, too, the time of the operation is shortened. The sulphuric acid remains unchanged by the process; but we are not yet in a condition to give a full explanation of its action. It can be removed from the saccharine liquid by carbonate of lime. According to calculation every 100 kg. (220 lbs.) of dry starch should furnish 108 kg. (238 lbs.) of dry sugar, corresponding to 120 kg. (264 lbs.) of crystalline starch-sugar, that is, if the transformation into sugar were a perfect one.

We again most emphatically assert, that a complete transformation of starch or dextrine into starch-sugar can never occur in practice. Anthon has proven that a perfect transformation of starch into sugar could only occur at that point of time (for instance after the lapse of 36 hours or even longer) when, by the simultaneous action of the sulphuric acid upon the sugar that had been formed many hours previously, large quantities of other products accumulate in the sugar solution. But in such a case there would be not only nothing gained, but the matter would be rendered even worse, since the products of decomposition thus formed would be of greater injury for all possible uses of starch-sugar than the small quantities of dextrine would be, which might be retained in the finished article.

By a too long-continued boiling of the starch with

sulphuric acid an entirely useless product would be obtained.

The transformation of starch into starch-gum and starch-sugar by diastase (malt), occurs most rapidly and completely at the so-called mash temperature of 60° to 65° C. (140° to 149° F.). The formation of soluble starch in this case takes place but during a very short period. Starch-gum and sugar ensue simultaneously, and it is not possible that the starch-gum itself can be completely transformed into sugar even by a continued action of the diastase. Hence a product results which always besides sugar still contains a considerable quantity of starch-gum. But if to the solution thus obtained some sulphuric acid is yet added (about 1 per cent.) and then boiled, an approximately complete transformation of the starch-gum into sugar will take place, especially if the boiling is done under pressure.

From these general introductory remarks the following results for practice are gleaned: Pure, solid, hard crystalline starch-sugar can only be produced by means of sulphuric acid, and only by a long-continued boiling. By a less-continued boiling of the starch in sulphuric acid water, a glucose is produced which contains considerable quantities of starch-gum (or an intermediate product between gum and sugar). The sugar thus obtained is not hard and crystalline, but soft and tough, and becomes moist in the air. From a syrup thus produced, by a not so long-continued boiling, no solid sugar separates, because the starch-gum prevents the separation. In a syrup obtained by a long-continued boiling, ensues in time, a separation of starch-sugar in a grainy condition. This is not a desirable product, and is considered as spoiled glucose. Syrup prepared by means of malt alone contains a con-

siderable amount of starch-gum. By the application of sulphuric acid, after the use of malt, the gum can be transformed in a great measure into sugar. Grape-sugar can be made directly from potatoes, grain, rice, maize, moss, wood, fruits, honey, raisins, etc.

In the manufacturing industries, starch-sugar, or grape-sugar, and glucose made of starch only find consideration, and hence we will here treat more prominently the subject of the conversion of starch into grape-sugar.

The Manufacture of Glucose and Starch-Sugar from Starch.

For producing glucose and grape-sugar from starch on a large scale, sulphuric acid serves almost exclusively, while malt (diastase) finds only application for the manufacturing of glucose, and this even only in some isolated cases. Pure, solid, hard crystallizing sugar can only be produced by means of sulphuric acid, and by dint of continued boiling and by further refining of the first product (the stiff or coagulated sugar mass), yielded by this method. Meanwhile the transformation of starch into sugar will be considerably forwarded by adding to the sulphuric acid a small quantity of nitric acid. If the sulphuric acid does not act upon the starch for a sufficient length of time (by a too short boiling of the starch with the acid), a syrup will be obtained which yet contains very considerable quantities of dextrine. From this syrup no solid sugar will separate, since its ability to crystallize is checked by the presence of the dextrine. The product yielded—still absorbing moisture from the atmosphere—will remain soft, tough, and smeary. By a too long-continued

boiling of the starch in sulphuric acid water, however, the sugar will separate in a granulated condition, which is not desirable, and must also be regarded as a mistake of the manufacturer, except when the final result was intended for granulated sugar.

By an exclusive application of malt for manufacturing starch-sugar a pure article is never produced, because a considerable portion of the dextrine formed by the starch remains unchanged; and the complete transformation of the same into sugar occurs only by applying sulphuric acid after the malt has been used.

Starch-sugar produced from starch appears in commerce in five different forms, viz.: 1, *as starch-syrup;* 2, *as a sticky mass*, termed "*imponderable syrup;*"* 3, *as granulated sugar;* 4, *as common, solid sugar* (stiff or congelated sugar-mass); and 5, *as refined, solid, starch-sugar* (distinguished by its whiteness and sweet taste, which are secured by refining through boneblack).

The species of starch applied in the United States for the manufacture of starch-sugar is with but few exceptions almost always *corn-starch.*†

The Manufacture of Glucose-Syrup and Starch-Sugar from Starch by means of Sulphuric Acid.

The manufacture of starch-syrup or glucose and starch-sugar by means of sulphuric acid is divided into the following operations:—

The boiling of the starch in sulphuric acid water.

The removal of the sulphuric acid and the gypsum produced thereby from the solution.

Evaporating and refining of the sugar solution.

* Generally termed glucose in this country.

† In Europe it is potato-starch.

These labors are performed in the glucose manufactories in very various ways, and by the application of the most diverse mechanisms. Almost every establishment has its peculiar *modus operandi*. It should be further mentioned that in using corn-starch a somewhat larger quantity of sulphuric acid is advisable for the conversion.

The Process of Boiling.—The boiling of the starch in the water containing sulphuric acid is mostly and best performed in a wooden vessel (a vat or barrel rather higher than wide) by a direct admission of steam. This method has, however, the disadvantage of bringing too much water into the decoction. The lining of the vessel with lead is not necessary, but increases its durability. For manufacturing on a smaller scale a perfectly scoured copper kettle may serve, which can be heated over a direct fire.

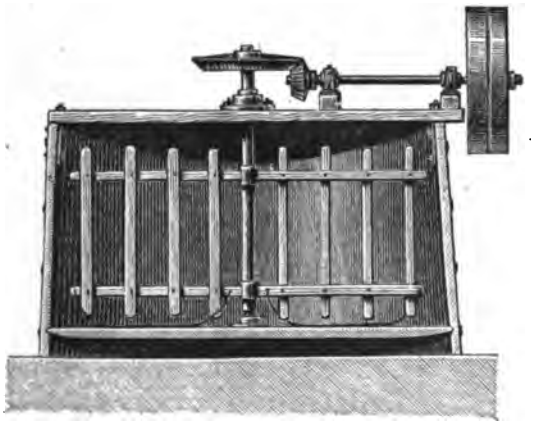
With regard to the construction of the boiling vat the following directions are to be observed:—

The starch-boiling vats were formerly constructed in such a manner that they could be heated with pressure. These vats were able to bear a great pressure, similar to that of a steam-boiler, with safety-valve, manometer, and air-valve. But despite all these precautions vats thus constructed offered but very little security, and it often occurred that by dint of the higher steam pressure the bottom of such vats would be blown out, thereby frequently causing great loss of life. Such vats exist even yet in some few of the older establishments, but are no longer used in manufactories of more recent construction. The only advantage which these vats of old construction offered was, that the process of boiling was somewhat shortened; but they had the fault, that the starch therein became some-

what thin and liquidy, because the steam entering into the mass in a direct way became condensed, diluting the mass down to 14° to 15° B.

In the modern stirring tub (see Fig. 28), on the other hand, a spiral pipe or *worm* made of copper is inserted through which the steam circulates. By this means the mass is brought to a boil, without being diluted, so that the same, after having done boiling, is usually of 19° to 20° B.

Fig. 28.



Stirring tub.

A great saving of fuel is one of the advantages gained, since 5° less is to be concentrated. The entire labor with this new apparatus is very simple, and not at all dangerous.

The following is an accurate description of such a boiling apparatus:—

The staves for the vat are to be of good pine wood, 6.67 centimetres (2.63 inches) thick. The vat, in order to allow a boiling twice a day of 1500 kilogrammes (3300 lbs.) of green starch, should be 2.5 metres (8.2

feet) in height. Its diameter below is 1.75 metres (5.74 feet). and above 1.67 metres (5.48 feet); it is open above, with a cover to be laid on, and supplied with a chimney or funnel. The lid or cover consists of five or six parts, as it would otherwise be too heavy; the funnel stands firmly upon the right side, and this part is fastened to the boiling vat. The chimney is square, and is made of 2 centimetres (0.79 inch) thick pine boards, has a width of 26.67 centimetres (10.5 inches) in the clear, and is of such a height as to project over the roof of the establishment, in order to carry off the odor. The vat is placed upon a strong framework, of sufficient height that the boiled starch can run into the neutralizing-coops by means of spigots, which are placed above the bottom of the vat.

The copper worm has five or six windings or less, according to its heating surface, and should have only a diameter of 1.4 centimetres (0.55 inch), so that it may be inserted into the vat without trouble. The copper pipes, which are used for the construction of the worm, have a diameter of 6.67 centimetres (2.63 inches), and the rings are fastened with brass clamps. In the construction of the worm nothing must be made of iron; all screws and nuts must be of copper or brass, since iron will be dissolved by the acid containing substances. The worm is placed horizontally upon the bottom of the boiling-vat; the steam is carried to the worm through a pipe, which is affixed in the vat. The condensed water (the exhaust) escapes at the side through a pipe of 1.75 centimetres (0.69 inch) being connected with the copper worm through the wood of the boiling vessel and carried to the feeding apparatus of the steam boiler. The requisite quantity of water is placed in the vat, heating it to a boil, but

before this, adding the previously diluted sulphuric acid. Thereupon the starch, which has been mixed in lukewarm water until it has acquired a milky consistency, is gradually left to run into the vat from the stirring tub, as shown by Fig. 28, while the liquid in the boiling tub is kept at a constant boil. It is therefore most convenient for this purpose to place a stirring-vat, supplied with a stopcock, over the boiling-vat, the stirring-vat containing the starch-milk. The flowing of the starch-milk must be so regulated that the liquid in the boiling vessel does not cease to boil, and that a paste formation does not ensue, or at least be but of a transient nature. Inasmuch as the starch deposits itself quickly from the starch-milk, it must while it flows in be constantly stirred, for which purpose a stirring apparatus may be placed in the vessel. Instead of permitting the starch-milk to flow in constantly, the flow is occasionally interrupted, and this must needs be done, if the liquid in the boiling apparatus does not continue to boil, and in consequence of a formation of paste becomes thickened. The larger the quantity of the boiling liquid is, the less readily it will cease boiling, and the less a paste formation will ensue. If no stirring-vat for the starch-milk is placed over the boiling apparatus, the starch-milk must be poured into the boiling sour water in portions.

To each 100 kilogrammes (220 lbs.) of air-dry starch from 150 to 200 litres (39.6 to 52.8 galls.) of water, and generally 2 kilogrammes (4.4 lbs.) of sulphuric acid are used, when glucose is to be produced; for the manufacture of solid sugar, the amount of acid may be increased to 4 kilogrammes (8.8 lbs.), in order also to shorten the time of boiling. In the amount of water stated, the water for stirring the starch is in-

cluded, and hence the entire amount of the water is not placed in the boiling vessel, but as much less as is already contained in the starch-milk. Meantime it should not be deemed necessary to scrupulously adhere to the prescribed quantity of water, a little more or less is of little consequence, but the worm in the converter must be covered. Inasmuch as the starch used in glucose factories is generally also prepared therein, and since the moist (green) starch can be well preserved in vats and barrels, the starch is most generally applied in a moist condition; and hence, instead of using 200 kilogrammes (440 lbs.) of dry starch 300 kilogrammes (660 lbs.) of green starch are taken, that is, one-half more than is taken of the dry article. The amount of water contained in the green starch, is of course counted in with the amount of water, which is applied for the mixing of the same.

Respecting the boiling by steam, it should be remarked, that the quantity of the water, which is poured in a cold state into the boiling apparatus, will increase about one-fifth by heating to a boil, and that even during the process of boiling an increase of the liquid ensues. By boiling over a direct fire, the liquid diminishes constantly by evaporation, and thus necessitates the replacing the evaporated water from time to time with pure boiling water.

After the entire quantity of the starch-milk has run in or is poured in, the boiling is continued until the intended transformation is accomplished. If glucose is to be produced, the boiling process is of shorter duration than in the case of manufacturing solid sugar, in which case the quantity of the sulphuric acid to be applied is to be larger.

During the boiling of the starch with sulphuric-acid

water, a very disagreeable, penetrating odor is developed, which becomes quite unbearable to the vicinity.*

At short intervals the liquid is tested, first with a solution of iodine, and afterwards with alcohol. For the test with a solution of iodine, a few drops of the liquid are placed in a test-tube, diluting the same with cold water, then adding a few drops of the solution of iodine. Whenever the liquid is no longer colored violet or reddish by the reagent, the transformation into gum and sugar is finished.† When this point is reached the test with alcohol begins. A few teaspoonfuls of the liquid are now placed in the test-tube, and an equal or double quantity of the volume of strong alcohol is added. The stronger the white separation caused thereby appears, the larger is the quantity of the starch- or dextrine-gum still present. If the precipitation by means of alcohol finally ceases, the starch-gum is nevertheless not entirely changed into sugar. A secure and simple means for determining the complete transformation into sugar is not yet known.

The Removal of the Sulphuric Acid; Process of Neutralization.—As soon as the intended transformation of the starch is attained by means of a sufficiently long boiling, the sulphuric acid is to be removed from the liquid. This is accomplished by the application of carbonate of lime. The sulphuric acid decomposes the lime, and under a lively efflorescence the carbonic acid gas escapes, and insoluble sulphate of lime (gypsum) is produced. The liquid thereby loses its acidy reaction and becomes neutral. This operation

* This refers principally to potato-starch, as corn-starch does not contain so much fusel oil.

† The product thus obtained is glucose.

can be accomplished in the boiling apparatus itself. In most cases, however, this operation is performed in neutralizing vats. Such a vat is a flat vessel, whose height stands to its width in a proportion of 1 to 3. The neutralizing in the boiling vat, although feasible is, nevertheless, troublesome, as that vessel will have to be washed out previous to each new operation.

The most suitable carbonate of lime for the process of neutralization is *chalk*, but even pure limestone, when free from clay, can be applied for this purpose. But it is indispensable to grind these articles into a fine powder. Of this powder a handful is thrown at a time into the hot, acidy liquid, by constant stirring with a paddle and mixed until no further ebullition ensues. If too much is thrown in at once it might involve the danger of overrunning.*

For each kilogramme (2.2 lbs) of sulphuric acid contained in the liquid, one kg. of pure carbonate of lime is required for neutralizing. But of chalk and limestone something more must be taken, since these articles are not entirely pure carbonate of lime. An excess, however, has to be avoided, in order not to unnecessarily increase the sediment.

The diminution of the acidy reaction during the adding of the carbonate of lime, can be tested by litmus paper—the paper becomes gradually less reddened. As soon as the paper shows a perceptible decrease of the sour reaction, the liquid is allowed to boil for a short period before a new portion of the carbonate of lime is added. The liquid can hardly be obtained entirely neutral; the cessation of effervescence must therefore

* Some manufacturers apply the chalk in bags, whereby the settling and refining are simplified.

guide the neutralization. The point when neutralization ensues is best approached by applying at the final process some chalk-milk wherein the carbonate of lime is very finely divided. For this purpose powdered chalk is stirred in water to a milk, and used after the coarser parts have settled to the bottom.

Since quicklime can be slaked in water to a very smooth paste, by means of which the sulphuric acid becomes perfectly neutralized, without ebullition, the question may be asked, why this article is not chosen if only for the purpose of avoiding the grinding of the chalk or limestone. The application of slaked lime is inadmissible because it destroys the starch-sugar. It is impossible to add the lime-milk to acidy sugar liquor in such a manner that neither locally nor transitorily too large an amount of lime comes in contact with the sugar. Whenever this occurs there will instantly be produced brownish products of decomposition of the sugar, by which the liquid is colored, imparting to it a bitter, caramel-like taste.

The neutralization being completed, the muddy contents of the boiling-tub are left to run into a depositing tank—a wooden tank—of greater height than width, which is supplied with cocks or spigots for drawing off the liquid. In the larger manufacturing establishments there is to be found adjacent to the boiling apparatus a reservoir placed in the ground and lined with brickwork. Into this reservoir the contents of the boiling apparatus are drawn, and afterwards pumped into the depositing vat. If several boiling tubs or converters for boiling with steam are used, they may be used at the same time as depositing vats.

After the lapse of from twelve to twenty-four hours the gypsum has become deposited, so that the saccha-

rine liquid may be drawn off. The sediment or the sugar phlegm, of course still contains a considerable amount of saccharine liquor. For the recovery of this residuum various methods have been recommended and applied.*

To this end filtering-barrels can be applied. They consist of vertically placed barrels, each with a sieve bottom. Above the sieve bottom a piece of coarse cloth is spread; upon this cut straw or coarse river sand is placed, and the residuum is carefully placed thereon. The liquid will then run out by the stopcock—placed on the lower bottom—pure and clear. The first portion, coming out still somewhat muddy, is placed back upon the filter. Upon the residuum gypsum water is carefully poured, after the upper layer has been made even, and is somewhat loosened. Thereby the yet absorbed sugar liquor is dislodged; or the residue is strained through bags or cloths, the press cakes being again saturated with water, and the pressing is repeated.

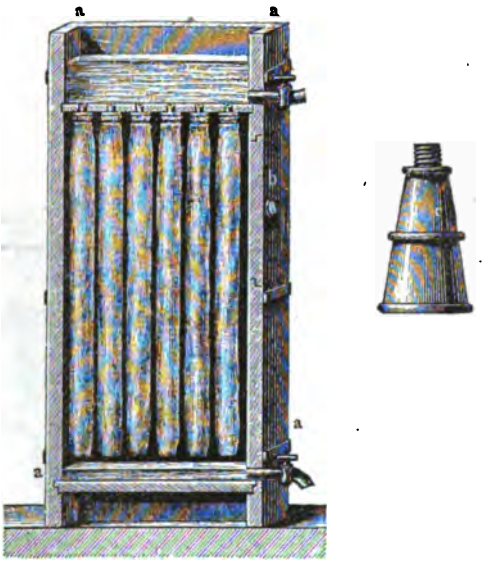
In most establishments, the removing of the sugar liquor from the sediment is frequently accomplished by the use of the bag-filter. The arrangement of these filters is delineated in Fig. 29. They consist of a series of long and small bags or sacks,† which are hung up in a wooden or, better, an iron closet-like case, with a

* In this country, in order to accelerate the process, the bag-filters are of a very large capacity. The liquor after being neutralized is run through them at once, thus saving the time absorbed by the use of settling-tubs.

† Such filter-bags consist of (*a*) the inner bags, made of a coarser material than the outer (*b*), great care being necessary to obtain for these latter a material strong enough to prevent the opening of the meshes, by the great weight of the filtering substance. Strong unbleached muslin may be recommended for the purpose.

double bottom. The space on the top forms a reservoir for the liquor or residuum which is to be treated. The lid of the case is perforated with holes, into which iron mouthpieces of the shape *C*, or simple pieces of pipe

Fig. 29.

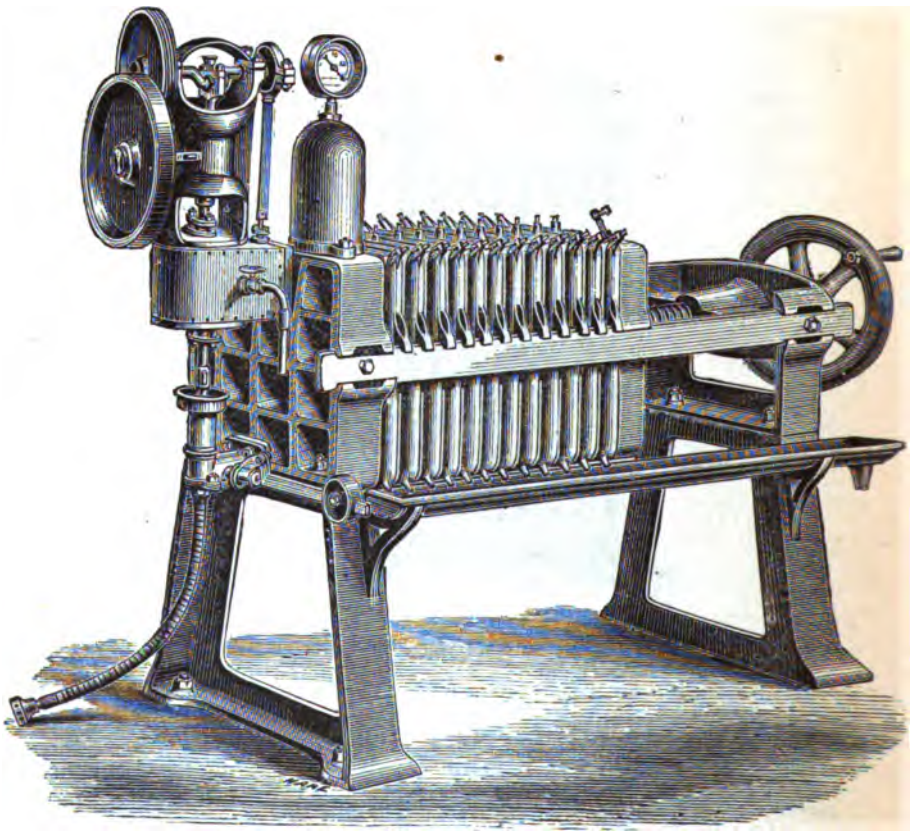


Taylor's bag-filter.

are inserted, which have on the one side screw-threads and on the other little collars, upon which the bags or sacks are tied. Generally these bags are double, of cotton and linen, the inner bags much wider, and consequently having folds, and are thus better adapted for filtering, while inserted in the outer bag. In the lower part of the box a drain pipe is inserted, for drawing off the clear juice, and on one of the sides is the gate *b*, for arranging the hanging up and taking down of the bags. When the bags containing the deposit are so filled, that no more juice runs out, they

are taken out and brought under a screw-press, whereby a large amount of the liquor still retained therein runs out, while the residuary matter remains in a dense and solid form.

Fig. 30.



Johnson's filter-press.

Fig. 30 illustrates a filter-press manufactured by John Johnson & Co., of 394 Oakland Street, Brooklyn, E. D., New York, which is extensively used for pressing out the liquor yet held in the paste-like residuum found in the bags, after the other liquor has run

through clear, as well as for the filtration of heavy glucose or grape-sugar syrup, to separate the fine particles of sulphate of lime deposited during evaporation, which are held in mechanical suspension throughout, the syrup causing a cloudiness or dull appearance, which must be dispensed with to complete the refining process.

Johnson's filter-press consists of a series of round or square plates, usually cast iron, having projecting lugs cast on each side, for the purpose of supporting them in a press frame in juxtaposition, face to face, and are capable of being screwed up tightly between the head and follower of the press. The plates are concave on each side, the projecting outer rim or edge being truly surfaced maintains the plate surfaces at distances corresponding to the depth of such rims. The plates are covered with suitable filtering cloth, and the method which the Messrs. Johnson employ for fixing the cloths on their filter-press is decidedly the simplest and most effective yet introduced. We will give a brief description, which will enable our readers to form an intelligent idea.

The passage of inter-communication by which the liquid arrives at the series of cells being formed by a simple hole, generally through the centre of each plate, a pair of cloths are used to cover each side of a plate, and these cloths are sewn together round the centre hole corresponding to the hole in the plate. It is obvious that on folding one cloth and passing it through the hole in the plate, and then opening it out on the other side of the plate, both surfaces will be suitably covered, the edges of the cloth passing between the surfaced rims of the consecutive plates, thus improving and simplifying the means of clothing the filter-

press. The upper part of the cloth is held in position by adjustable tension hooks, which provide for the shrinkage or slackness of the cloth, and are also provided with ribs or channels on the plate surface under the cloth, to allow the filtrate to flow away to the outlet formed in the bottom of the filter plate at the back of the cloth. The spaces between the cloth-lined plates form chambers or cells, into which the liquid or semi-liquid material to be filtered is forced under pressure. A passage or opening, also lined with cloth, is formed through each plate, so that there is a free communication between the several filtering cells. When the liquid or semi-liquid material to be filtered is forced into this battery of cloth-lined chambers or cells, the liquid is forced through the filtering cloths which cover the plates, and flows away to the outlet of the plate by following the channels or grooves in the plates, which have free communication with the outside of the filter. The solid matter, sulphate of lime, etc., is stopped back on the surface of the cloth, and by a continuance of the operation ultimately fills the cells, and can be removed from between the two cloth covered concave plates, forming any one of the chambers, by unscrewing the press and separating the plates, in a state of almost perfect dryness, without removing the cloths.

The Process of Evaporation.—The evaporation of the obtained clear—or at least tolerably clear—sugar liquor can be accomplished either over a direct fire or by steam. In the first case flat pans are used, whose bottoms are only touched by the fire; in the other case the various vacuum pans and apparatus serve as being best suited for the purpose of boiling down the sugar liquor. The process of evaporating cannot be finished

uninterruptedly, since the solution of sugar yet contains dissolved gypsum, which begins to separate during the evaporation, and by leaving the liquid stand over when it has evaporated to a certain point, the gypsum is separated as completely as is possible.* The evaporating, therefore, although at first it may take place by lively boiling, is divided into two periods: the evaporation to the degree of a thin syrupy consistency, and the evaporation to the consistency of a denser syrup, after the removal of the gypsum. It does no harm, and especially not in the manufacture of glucose, to add sugar liquor to the pan in the same ratio as the contents of the pan diminish by evaporation. The scum produced during the process of evaporation is taken off with a skimmer.

As soon as the separation of the gypsum makes it necessary, or when otherwise the liquor has reached a concentration of from 20° to 30° Baumé = 37° to 57° of the saccharometer, it is transferred from the evaporating-pans into upright barrels, provided with stopcocks or spigots for depositing and separating the gypsum. When finer cloths are put into a filter press, the latter may also be used for removing the separate gypsum. If this has been accomplished, after the lapse of several days, then the clear liquor is drawn off and evaporated in the same pans, or in extra pans, to a dense syrupy consistency, *i. e.*, from 40° to 45° Baumé. In larger manufactories, *vacuum-pans* are used for this purpose.

* I have found that a liquor evaporated to 30° B., and left to settle for a long time, did not prevent a fresh separation of gypsum, when the evaporation afterwards brought the liquor to a higher density. An extra chemical treatment is necessary to eventually bring forth a clear and transparent syrup —*Hutter.*

The deposits of gypsum from the barrels are placed in bag-filters, and after draining off pressed.

The evaporation of the sugar-liquor in open pans does not allow of a corresponding utilization of the steam or fuel, besides which the liquor—while exposed to too high a temperature—receives a dark color, and finally, at the finishing of the boiling of the sugar-liquor, a strong formation of scum will ensue.

In order to avert these troubles, closed evaporating apparatus has for some time been used. Its object is, in the first place, the evaporation of the saccharine liquor under a diminished atmospheric pressure. By this mechanism it becomes possible, to apply, in place of the direct steam from the boiler, that which has already served for the working of the steam-engine (exhaust steam). The temperature of this steam having decreased correspondingly, becomes thus better adapted for the purpose. Or that steam is utilized which has been used in the evaporation of the liquor.*

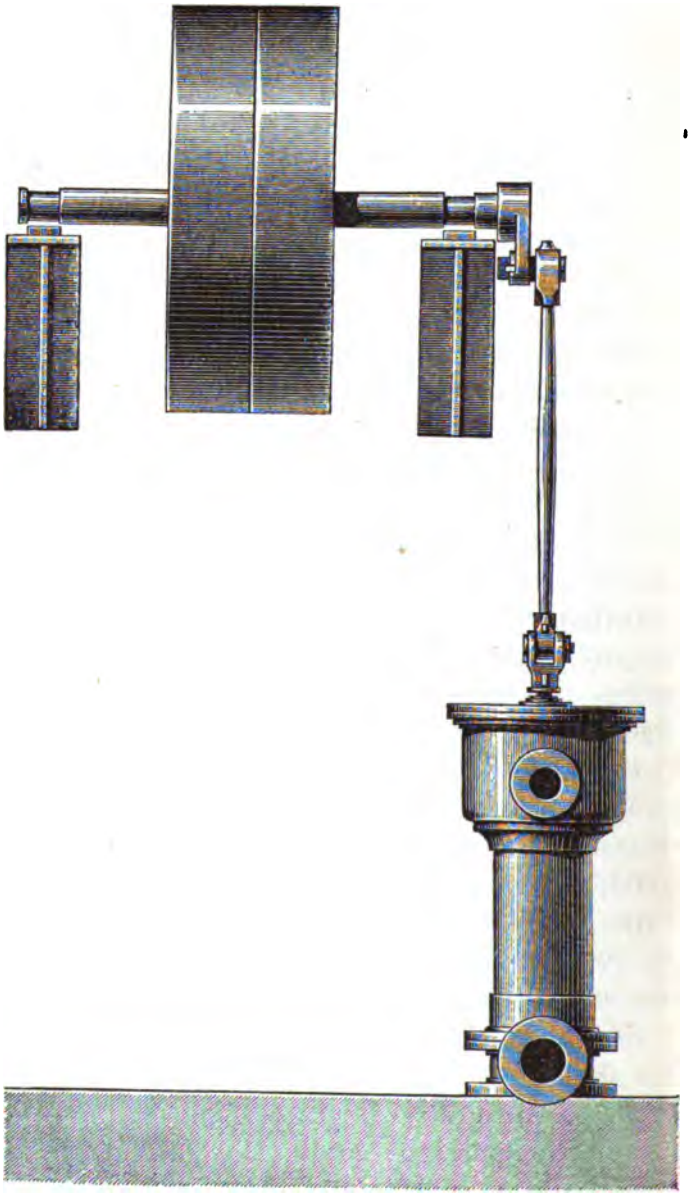
As is well known, liquids will come to a boil at a considerably lower temperature, by diminution of the atmospheric pressure. The rapidity with which the water evaporates from the saccharine liquor in the first place depends on the difference of the temperature between the boiling liquor and that of the *worm*, which latter is inserted into the apparatus for increasing the act of evaporation, and is furthermore dependent on the extent of the heating surface of the worm. Inasmuch, however, as the saccharine liquor already boils at a diminished atmospheric pressure, *i. e.*, at a tempe-

* On the other hand, I have found by practical experience that such exhaust steam will never do, where a first-class white product is required, as the quality of the article depends entirely on a quick and uninterrupted evaporation.—*Hutter.*

rature considerably below 100° C. (212° F.), it becomes possible to re-use the steam that has already served for motive power, also for the purposes of evaporation. This return or exhaust steam, after escaping from the cylinder of the engine without pressure, has a temperature of 100° C. (212° F.). But whenever it escapes by a counter-pressure of one-third atmosphere, its temperature is about 107° C. (224°.6 F.). Such steam will serve with great advantage even for the evaporation of a liquor, which boils at 100° C. (212° F.). The difference in the temperature of the liquor and that of the steam is thus far certainly not considerable, but it can be increased by decreasing the boiling point of the liquor, and by diminution of the atmospheric pressure, for instance, to 94° C. (201°.2 F.).

It is self-evident, that in the application of this improved evaporating apparatus, care must be observed, that the vapors which are developed from the liquor are forced out by the vacuum-pump as fast as is possible. To this end, the vapors are brought into contact with cold water, by means of a second vessel (the condenser), in which the water is running, and the vapors are again converted into water, and in this state removed. The water has a volume of but $\frac{1}{1700}$th of that of the steam, out of which it has been condensed. For the removal of the condensation-water, an accurately constructed and powerfully acting suction-pump, as is illustrated by Fig. 31, serves, and which also simultaneously supplies the *vacuum* in the evaporating apparatus. Inasmuch as with the juice, and especially with the absorbing water, air will constantly enter into the apparatus again, this must needs be removed, if the requisite vacuum is to be maintained. The task of the pump—to force out both air and water—

Fig. 31.



Wet air-pump.

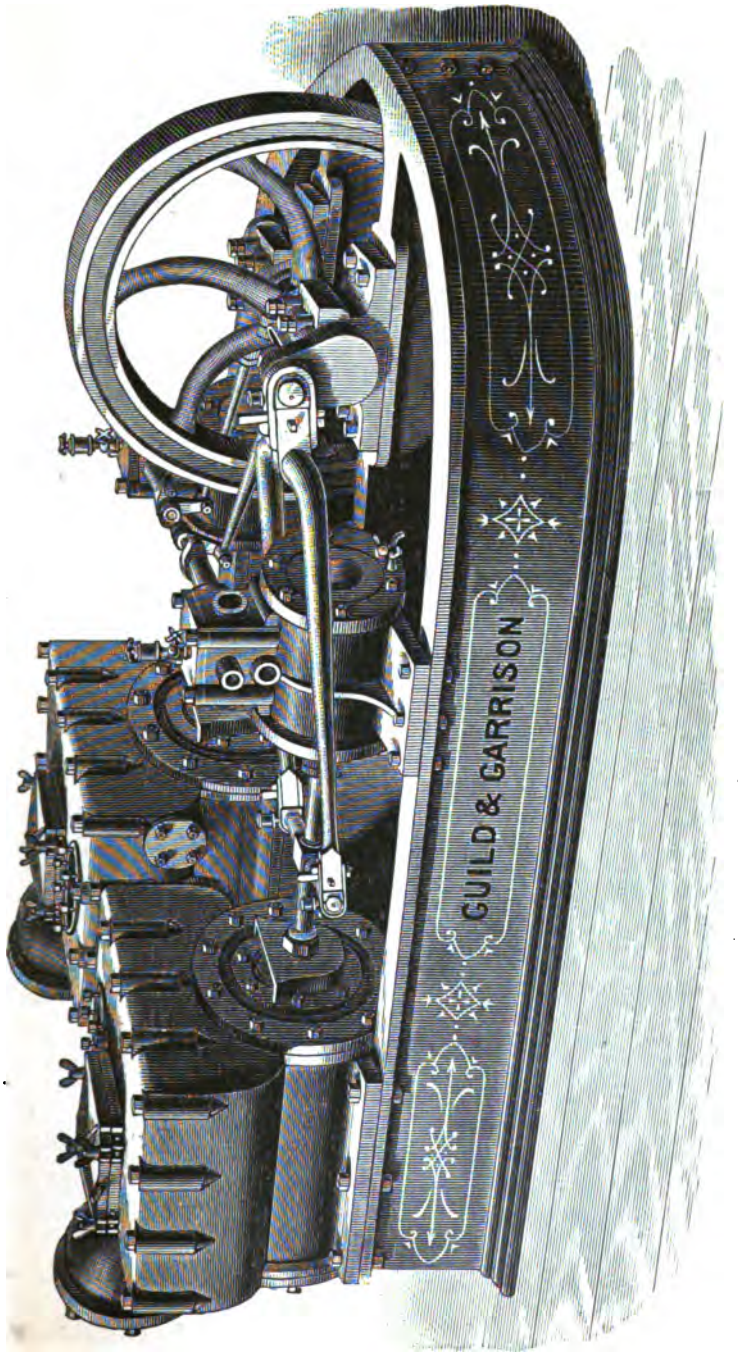


Fig. 32.

Guild & Garrison's vacuum pump.

never ceases. This service does not cease even then, when the process of evaporation in the apparatus is in full activity. For this reason this pump is called the "*wet air-pump.*"

We also present in Fig. 32 one of Guild & Garrison's pumps, which may be used as wet or dry pumps, working equally well under any circumstances, and are an independent vacuum-pump of the highest efficiency.

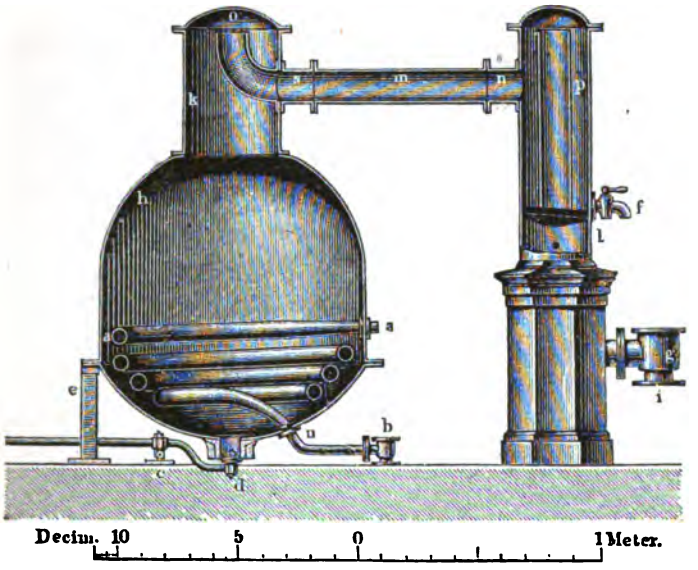
By the sketches, Figs. 33 and 34, are represented the longitudinal section and the upper part of a vacuum apparatus.

A is the boiling vessel (the vacuum), mostly of a more or less spherical shape. Upon this is placed the cylindrical *ajutage*, *C*, the dome, which is to prevent the boiling over of the liquor. From the upper part of the dome the pipe *m* conducts the vapors into the "overflow," from whence they enter into the condenser, *p*.

The liquids enter into the vacuum *A* through the so-called feeding pipe, which is closed by means of the "suction cock." For the purpose of admitting the various liquors and syrups which are to be evaporated, as well as the water (for cleaning the vacuum pan) from the respective tanks, usually four "suction pipes" (not visible in the sketch) serve.

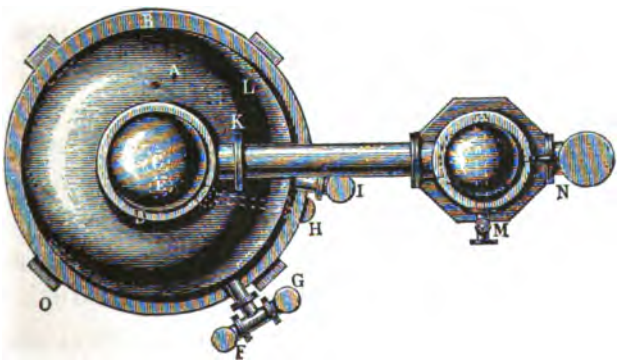
The heating of the liquor is accomplished by means of direct steam, which is conducted through the valve (shown in Fig. 33) from the steam boiler into the steam port *J*. The steam enters either into the worm *a a*, Fig. 33, or into the steam jacket of the vacuum pan. For the draining off of the condensed water and the uncondensed steam from the worm as well as from

Fig. 33.



Vacuum apparatus.
(Longitudinal section.)

Fig. 34.



Vacuum apparatus.
(Upper view.)

the double bottom, special "reversible cocks," *K* (Fig. 34) serve. For the admission of air and an easy outlet of steam from the double bottom of the va-

cuum pan, in order to effect a quick moderation of the temperature, an air-cock serves.

To the vacuum pan are attached a thermometer and a vacuum gauge. The apparatus is also supplied with a stopcock, *F* and *G* (Fig. 34), for the admission of air or *fat* (paraffine). In the upper part of the vacuum pan are placed two eye-glasses for the purpose of observing the boiling of the liquor *A* (Fig. 34). These eye-glasses are lighted by a lamp or a gas flame.

Another important piece of mechanism on the vacuum pan is the so-called proof-stick, by means of which a sample of the boiling juice can be taken out at any time for the purpose of examining the state of concentration without admitting any air. The vacuum pan is closed air-tight by a conical pin *d* (Fig. 33). This conical pin is affixed below, and is of cast iron covered with India rubber. It is pressed against the apex by the lever *c*. For cleaning the apparatus the manhole *B* (Fig. 34) serves.

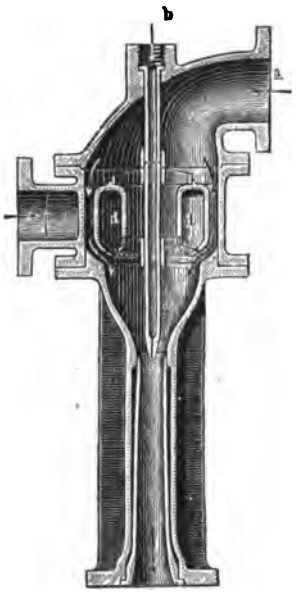
The vapors enter, as already stated, by the pipe *m* (Fig. 33) in the overflow and condenser *p*, where the injecting mechanism (the rose) is placed.

The letters on Fig. 34 designate the following important parts of the vacuum pan, some of which do not at all appear in the drawing: *A*, eye-glass with lamp; *B*, manhole; *C*, conical stopper; *D*, trial gauge; *E*, eye-glass; *F* and *G*, valves for admitting air; *H* and *I*, valves for admitting steam; *K*, exhaust valve; *L*, waste-cock; *M*, cock for injecting water; *N*, valve of the air-pump; *O*, lever for the conical pin.*

* Mr. G. F. Ott, 207 Buttonwood Street, Philadelphia, is making a specialty of vacuum pans of copper, wrought and cast iron, well adapted for evaporating sugar liquor, and of great merit.

Instead of vacuum pumps, more recently steam-jet condensing machines are frequently used (Fig. 35). This apparatus acts by means of a passing jet of water and by a fine stream of fresh steam. The outer casing

Fig. 35.



Vacuum steam-jet condenser.

of the apparatus consists of cast iron, the inner parts of brass. The condenser is erected vertically. At *a* is the entrance for the water; the water is admitted by a pressure of about 5 metres (16.4 feet). If a proper height for the fall is wanting, the water is either conducted from a correspondingly high reservoir, or by a pump of a like force. In case pumps are used in a direct way, an air-chamber must be inserted in the conduit of water in order always to have uniform pressure. At *b*, a jet of fresh steam is admitted by means of a hollow needle, which by its swiftness increases the effect of the water

forced through the jet. As is evident, the steam becomes by its contact with the water condensed. At *c*, the evaporating-pipe, which issues from the vacuum-pan, is connected. The *vacuum* attainable by this mechanism borders on the absolute; of course under the condition that all parts of the apparatus are fitted air-tight. This apparatus requires for each 1 weight part evaporating vapors 30 weight parts of water for condensing, and one-tenth weight part of fresh steam, or thus expressed, 1 litre (2.1 pints) of water to be evaporated requires 30 litres (7.9 galls.) of condensing water and 0.10 kilogramme (0.22 lb.) of steam. The impelling power of the steam-jet condenser begins by opening, in the first place, the water conduit, thereupon admitting the fresh steam, and then conducting the evaporating fumes to it. The turning off is accomplished in reversed order.

The "steam-jet condensers" are made of various sizes, and of any desired capacity.

Inasmuch as a nice brown color is much desired for glucose-syrup, if it is intended to serve as a substitute for the syrups of the East or West Indies, or as an admixture with the latter, a discoloration by means of boneblack is not always demanded.

If the syrup is not to be discolored, it is boiled down in the vacuum-pan to 40° or 42° Baumé, weighed at 60° to 65° C. (140° to 149° F.), and thereupon again forced through the filter-press. For this operation the first filter-press may be used, after a previous cleaning of the same; but it is better to set up a second press for this purpose, which may be of smaller dimensions. Of course the syrup, while passing through the filtering-press, must be kept at a correspondingly high tempe-

rature (75° C., 167° F.). The filtering-cloth for this operation is of a lighter quality.

But if, notwithstanding, the saccharine liquor is as usual passed through filters of coarsely powdered animal charcoal (as is done in beet- and cane-sugar manufactories), or if the refining is carried out with fine charcoal and blood, this is also done for the purpose of producing the syrup absolutely discolored like water, and to refine its taste.

The filtering through boneblack is accomplished most rationally at a degree of concentration of 32° Baumé, weighed at 60° to 65° C. (140° to 149° F.) of the liquor. This is to be done, after the gypsum has deposited itself from the evaporated liquid, by means of a prolonged rest. The liquor must, however, previously be heated again. If starch-syrup or glucose is for an extended time kept at a temperature near its boiling point, it assumes a darker color, becomes sweeter, and loses more and more the tendency to crystallize.

For the manufacture of the solid starch-sugar but little need be added to the preceding. Whether the starch-syrup thus obtained remains liquid, or in time congeals into solid, grainy, starch-sugar, depends, not so much on its concentration, as on the quality of the same. If the operation has been so manipulated that in the syrup, besides sugar, a certain quantity of starch-gum (dextrine) is still present, the syrup will remain liquid, even at a very considerably high degree (45° B.) of concentration. If the aim has been most completely to transform the starch into sugar, *i. e.*, if sulphuric acid has been applied in larger quantity, and the boiling continued for a longer period of time, a syrup will result, which already by an inferior concentration will in time separate grainy sugar, and by increased con-

centration will gradually entirely congeal to a grainy sugar. Such syrup is permitted to stand in moderately warm rooms, in wooden vessels or in earthen basins, until it congeals. For producing a solid, white sugar, the treatment of the saccharine liquor with boneblack for the purpose of discoloring is indispensable.

The liquid syrup or glucose is generally packed in strong casks or tuns of soft wood, and is even, despite the greatest care, exposed to the danger of a large degree of shrinkage. During hot weather its transportation is almost impossible, since the syrup absorbs the water contained in the wood, and in consequence thereof the casks become dry, and the syrup leaks out. In case the boiling process has not been properly attended to, the article will easily ferment and spoil.

These great obstacles and difficulties of the syrup traffic and transport are overcome by introducing this article to commerce, at present, principally in a coagulated, more solid form, that of *crude* or *refined grape-sugar*. The syrup boiled down to a corresponding concentration can by means of a simple mechanical manipulation easily and quickly be turned to a perfect *congelation* or *coagulation*. Already in 1865 the peculiarity of the starch-syrup was known under certain conditions to coagulate in a spontaneous way; as, for instance, after having been for a longer time deposited in warehouses, or whenever it is heavily jolted for a longer period during its transportation. Upon this peculiar property of the starch-syrup rests the mechanical manipulation whereby it is caused to become stiff. If the starch-syrup has finished boiling it is, after cooling off, diligently stirred or beaten. Thus treated it will coagulate or congelate within eight or ten hours so perfectly

as to assume a soaplike consistency, without, of course, altering its quality. In this condition it can be far better preserved and more easily transported. It can in this state be cast into suitable forms, and may be transported in very light cases made of thin and soft wood, and can also be handled much better and more satisfactorily.

In the present state of the development of the glucose-syrup and sugar manufacture, both the coagulation of the glucose and the longer period of the sugar remaining liquid are considered as faults, and justly so. From this it becomes clear that the liquid glucose having the property of coagulating very quickly cannot be adapted to form an article of the syrup trade, because neither manufacturers nor consumers will designate it any longer as syrup, or treat it as such; but from the time of its coagulation it will hence pass only as grape-sugar.

The products of starch-syrup and the starch-sugar manufacture may thus be classified:—

a. Starch-syrup,* an article which for a comparatively long time remains clear and liquid.

b. Common starch-sugar, obtained by congelation of starch-syrup, and being characterized by containing a relatively large amount of dextrine.

c. Purified or refined starch-sugar, obtained by a repeated refining of the common starch-sugar.

d. Granulated starch-sugar obtained by congelation, but containing the smallest possible percentage of dextrine.

If the product is to be disposed of as solid sugar, and not as syrup, the liquor is evaporated in flat eva-

* The commercial term for this is glucose.

porating vessels, to from 40° to 42° B., and then placed in crystallizing pans. After the crystallization has commenced the sticky liquid is filled into small barrels wherein the mass after a short time entirely coagulates, and can thus be shipped. The mass may also be allowed to become solid in the pans, and then be ground and packed. Some manufacturers produce a dry and grainy sugar. The sugar-formation from starch in this case is manipulated in the same manner as stated above. It is of importance that the transformation hereby of the starch into sugar ensues as completely as possible, since the presence of greater quantities of the remaining dextrine will hinder the granulation.

Starch-syrup in the liquid state, or glucose, and the crude or common grape-sugar are, as regards their quality and price, simply *one and the same product*, however much they may differ in external appearance. Both these articles, the starch-syrup and the starch-sugar, still contain much unchanged dextrine or gum. This article is thrown out from the refined granulated grape-sugar, and is known as molasses. We have already stated that the complete transformation of the dextrine in the starch-syrup can only be accomplished at the expense of the quality of the product, since by the too long-continued boiling products of decomposition will be created, possessing a disagreeable, bitterish taste, and thus causing the syrup, or the common grape-sugar, to become unfit for consumption and valueless. A total transformation of the dextrine into sugar has proved, for the reasons stated, as entirely impracticable.

The common grape-sugar is therefore, as regards its chemical ingredients as well also as the action of these ingredients on each other, entirely identical with the

liquid glucose. But in general the composition of the common starch-sugar, or that of the glucose, is so varied that scarcely two samples of the article can be found which possess an equal percentage of the composition of their ingredients, as may be seen from the subjoined analyses:—

	Liquid starch-syrup or glucose.		Common starch-sugar (stocked starch-sugar).		
	I.	II.	III.	IV.	V.
Water	21.8	20.8	27.8	27.4	26.0
Sugar	42.2	56.0	56.2	58.8	61.5
Dextrine and intermediate products . . .	35.4	22.6	15.6	13.3	12.0
Mineral ingredients . .	0.6	0.6	0.4	0.5	0.5
	100.0	100.0	100.0	100.0	100.0

From these analyses of the liquid starch-syrup and the common grape-sugar, as obtained from different sources, it can be seen that both these products are in fact mixtures composed of water, dextrine, mineral substances, etc., with a quantity of starch-sugar varying from 42 to 65 per cent. It will be perceived that they will form, neither in a liquid nor in a solid condition, a pure starch-sugar, and that especially the starch-syrup in solid form, bearing erroneously in commerce the name "starch-sugar," is yet far from being *solid, pure starch-sugar.*

Special Directions for the Manufacture of Starch-sugar.

Payen's Method for the Manufacture of Starch-syrup and Sugar.—According to the directions of Payen the boiling, or the conversion of the starch into sugar, is to be performed in large and very thick vats or tubs of wood *A A* (see the illustration Fig. 36). Each of these vats has a capacity of 125 hectolitres (350 bushels);

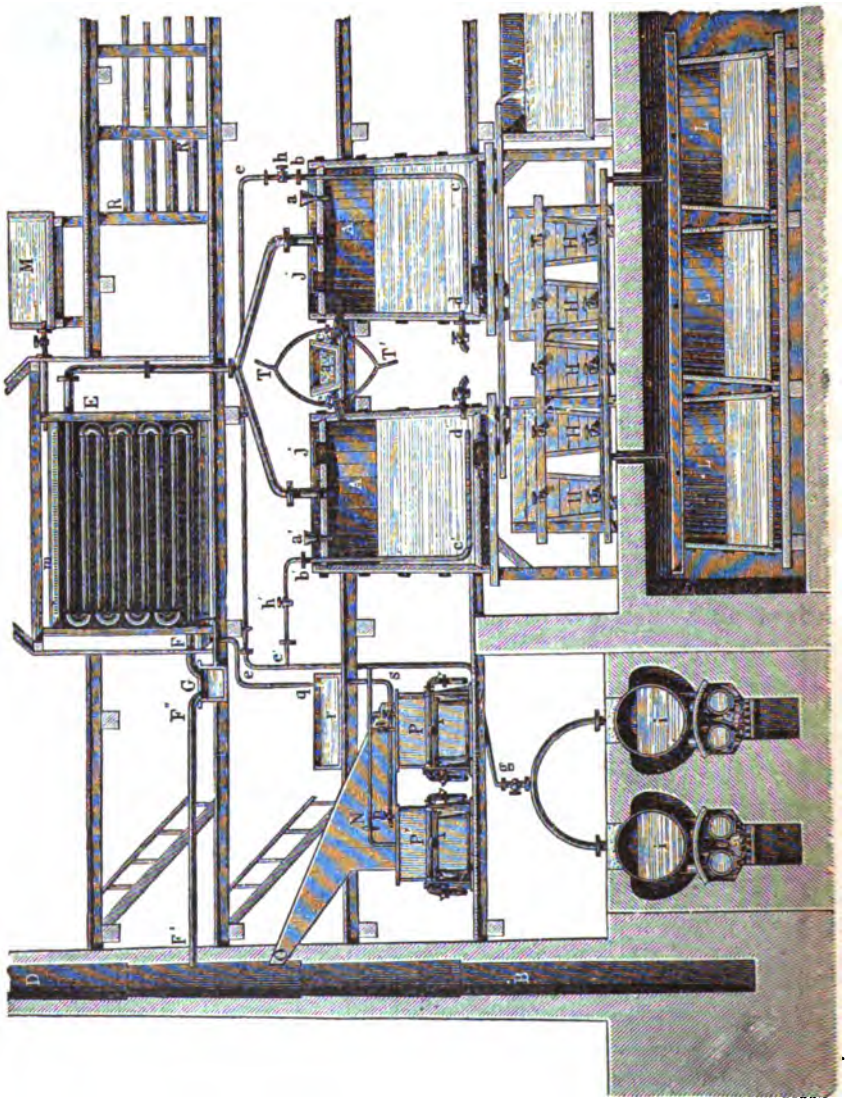


Fig. 36. Payen's apparatus for his method of manufacturing glucose.

their staves have a thickness of about 10 to 12 centimetres (3.9 to 4.7 inches). A lead pipe *b c d* runs into the vat *A* to the bottom *c d*, the part *c d* is there on the

bottom bent into a circle, and at short distances slits are made in the pipes by a saw.

The vat is filled to about one-third of its capacity with sulphuric acid water, and then the liquid is heated by steam. This is done by admitting the steam from the boiler *i* through the copper pipe *g e e b* (which near *b* can be stopped off by the stopcock "*h*") and by the leaden pipe *b c d* the steam enters the vat. During the boiling the vat is covered, and the vapors drawn off are immediately conducted into a chimney, or they pass through a main pipe into the horizontally placed worm *E F*, to be utilized for the process of evaporation. This drawing off of the vapors becomes necessary on account of the bad odors which are developed by the heating of the starch with acid, and originates from the oily contents of the starch.* If these vapors escape at once through the chimney the stench will become quite troublesome to the neighborhood, while by the cooling off in the pipe the volatile oil becomes in a great measure condensed with the steam, and thus collects between the pipes *F* and *G* in the vessels which are placed below it. In this way the non-condensed parts escape through the pipe *F′ F‴* along with the vapors, and as they are thus weaker, and there is less of them, they become not so noticeable. In order entirely to destroy these vapors they may be conducted into the fireplace under the boiler instead of passing through the chimney.

In the present case we pour into the vat (boiling-coop) about 3000 kilogrammes (6600 lbs.) of water, mixed with one-half of the sulphuric acid necessary for

* Potato-starch has more of these oily contents than corn-starch.

the transformation of the starch. The water thus acidified is heated to 100° C. (212° F.).

Meantime the quantity of 3000 kg. (6600 lbs.) of the commercial dry starch is placed in a vat of corresponding size, and set above the boiling-coop. In this other vat the other half of the requisite sulphuric acid (in the present instance from 30 to 60 kg.) (66 to 132 lbs.) and a corresponding quantity of water have previously been poured in order to produce the starch-milk. This starch-milk is admitted into the boiling-coop by a cock which is situated in the bottom of the upper vat, and should run in a uniform stream through the funnel *a* into the boiling vat, commonly called the converter. The smaller the quantity of water, in comparison to the amount of starch to be converted, the more care must be taken during the admission of the starch-milk into the boiling-coop, so that the boiling of the liquid is not interrupted even for a moment, so as to avoid the formation of a paste, a serious matter during the course of the formation of sugar. By the gradual admission of the starch-milk the temperature of the mass increases constantly, so that it finally reaches that of the boiling-point of an equally concentrated sugar solution.

If, finally, all the starch-milk has passed into the boiling sulphuric acid water—requiring from one to one and a half hour's time—the boiling is yet continued from two and a half to three hours, in case of the production of glucose, but in the case of sugar the period is from four to six hours. A longer boiling furnishes a colored article of a bitterish taste, without attaining a perfect sugar formation. The progress of the transformation is noticed by the iodine and alcohol test.

When the transformation is finished the free sulphuric acid is removed from the liquor. This is accom-

plished by stirring finely-powdered chalk or limestone (carbonate of lime) in small portions into the heated liquor until ebullition no longer ensues. The carbonate of lime neutralizes the acid, since while the carbonic acid gas escapes, indissoluble sulphate of lime (gypsum) is formed. For each 1 kg. (2.20 lbs.) of acid a little more than 1 kg. of chalk is required. When the liquid is neutral it will not redden blue litmus paper, or at least but very faintly.

After saturation the liquor is allowed to settle for twelve hours. This can be done either in the coop itself, or in the reservoir (tank) *A''* which is placed thereunder, in case a new quantity of starch is to be at once transformed into sugar. Thereupon the clear liquor is drawn off and heated to 60° C. (140° F.), and refined through the filter *H H* by animal charcoal. The gypsum residue is placed by itself over a linen filter, and after dripping off washed out.

The saccharine liquor or thin juice filtered through the boneblack being 15° to 16° B. is collected in the lower reservoir *L L*, from whence it is raised by a pump into the upper reservoir *M;* from thence it flows off into the horizontal channel *m*, which is supplied with a number of slits, and from this it runs down through the side slits over the heated worm-shaped evaporator *E F*. Underneath this apparatus the syrup collects in a gutter *p*, and now flows through the pipe *y* into the reservoir *r*, where it is finally drawn off according to requirement, by means of the pipe *s* and the spigots *n n*, thence to run into the evaporating pan *P P'*. Over these pans is a casing of wood in order to conduct the steam into a chimney. The syrup is evaporated in these vessels to 30° B., whereby again some gypsum becomes separated, which must be re-

moved from the liquid by a prolonged depositing of the same.

The starch-syrup thus obtained is already serviceable for distillers and beer brewers, etc. For many other applications, however, as for baking, for cordials, etc., it must, after twenty-four hours, be again heated to 60° C. (140° F.), and filtered through coarse animal charcoal, whereupon the filtered syrup is immediately packed up in barrels.

This room- and time-wasting, troublesome, uncleanly, and loss-entailing older method, finds at present application in but few establishments.

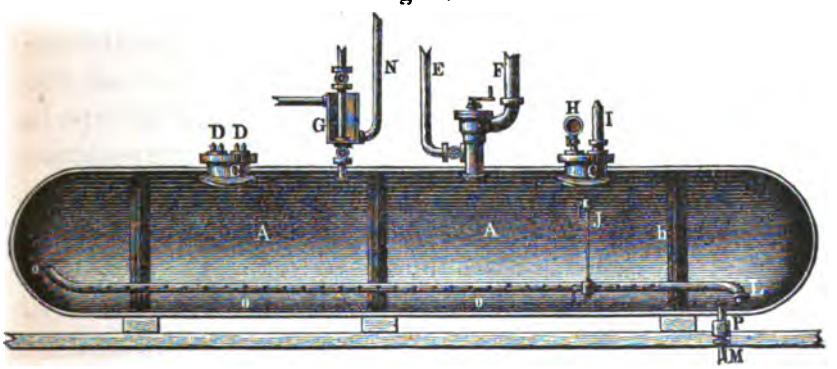
Maubré's Method for the Manufacture of Starch-syrup and Sugar.—As may be seen from the preceding the starch-gum, or dextrine, which besides starch-sugar is formed by the action of the sulphuric acid upon the starch must, by a continued boiling with the acid, be transformed as completely as is possible into sugar. This transformation, however, ensues by applying ordinary pressure but very slowly. For this reason most of the manufacturers who operate according to the old method, do not wait for the complete transformation, but rather prefer to furnish a sugar for the trade which holds a large amount of dextrine. The conversion of starch into glucose and sugar succeeds, however, all the faster when the boiling of the starch takes place under a higher pressure than the common atmospheric, or what amounts to the same, when the action of the acid upon the starch ensues under an increased temperature. Upon this fact rests *Maubré's* method of manufacturing glucose, patented in England in 1864.

The mixture of starch with diluted sulphuric acid is boiled at a high pressure, and at a temperature of 160°C. (320° F.). By this treatment the action of the sul-

phuric acid upon the starch is increased, the transformation of the dextrine into sugar is attained more perfectly, and, moreover, the forming volatile oils, which impart a disagreeable taste to the glucose, are distilled off and destroyed.

To attain this end a steam-boiler, in the shape of a high-pressure boiler, is most suitable. It is to be constructed of strong iron plates, so as to withstand a pressure of 45 kilogrammes (99 lbs.) per square inch (6 atmospheres); inside it is lined with lead, and outside is covered with a double casing. The intermediate space between the boiler and the casing is about 10 centimetres (3.9 inches) wide, and filled with a substance being a non-conductor of heat (sand, etc.). In the boiler *A A* (Fig. 37) is placed a perforated leaden

Fig. 37.



Maubré's apparatus for the manufacture of glucose.

pipe *o o o* for conducting the steam therein. For filling up the boiler with the starch-milk the conduit pipe *G*, which is supplied with a stopcock, serves; besides this the boiler is supplied with safety valves *D D*, the test-cock *H*, and the thermometer *I*; *C C* are the manholes; *E* is the receiving pipe for the products of dis-

tillation (the volatile and empyreumatic oils); *F* the pipe for the steam; *J* is the gauge showing the amount of liquor; *L* the pipe for admitting the steam; *M* the outlet-cock; *N* a pipe for admitting water.

The substances are prepared for the boiler in the proportions as follows:—

28 kilgr. (61.60 lbs. of sulphuric acid of 60° B. are diluted in 2800 kilgr. (6160 lbs.) of water. While this mixture is heated in the boiler to 100° C. (212° F.) a further quantity of 28 kg. (61.60 lbs.) of sulphuric acid is diluted in 2800 kg. (6160 lbs.) of water in an open wooden tank, which is supplied with a stirring apparatus. This mixture is heated by steam to 30° C. (86° F.). In this latter liquid 1120 kilogrammes (2464 lbs.) of starch are placed well stirred in and heated to 38° C. (100.4° F.) The starch-milk thus obtained is then gradually poured into the boiling diluted sulphuric acid of the boiler by means of the pipe *G*, and the ensuing mixture is kept at a boil. As soon as all the starch is in the boiler the cock of the conduit-pipe is closed and steam is now admitted, until a temperature of 160° C. (320° F.) and a pressure of 6 atmospheres are attained. Thereupon the cocks *E* and *F* on the outlet pipes are opened for the outlet of the steam, as also for the removal of the products of distillation, while the temperature of the liquid is maintained by means of steam (from the pipe *o o o*) at 160° C. (320° F.). Thus ensues an almost complete transformation of gum into sugar, as well as the perfect volatilization of the oils formed. The temperature of 160° C. (320° F.) is kept up so long, until samples taken out by means of the cock *P*, will indicate that the starch or the dextrine has been transformed into sugar. This is accomplished

according to the grade of the purity of the starch applied, in a period of from two to four hours.*

The test whether the starch or the dextrine has become transformed into sugar is determined by the reaction of iodine upon it, and by means of acetate of lead. The iodine reaction tends to prove that all the starch has become changed, while the acetate of lead will indicate the almost complete disappearance of the dextrine. Of course the sample taken out of the boiler must be previously neutralized, then filtered through a small charcoal filter, and only thus applied. After ceasing to form sugar the sweet liquor is to be drawn off for the purpose of neutralization of the sulphuric acid. It is drawn into an open wooden vessel which is supplied with a stirring apparatus and waste-cock. Thereupon 84 kilogrammes (184.8 lbs.) of purified carbonate of lime are stirred into 250 kilogrammes (550 lbs.) of water, and gradually added to the liquor. The sulphate of lime thus formed is allowed to deposit, which requires a period of from two to four hours. Finally, the neutral saccharine solution is filtered through bag filters, and evaporated to 35° B., cleared with blood and boneblack, again filtered through bags and boneblack filters, and then crystallized.

The sugar thus manufactured is entirely pure and free from any bitter or *empyreumatic* taste.

Landmann's Method of Manufacturing Starch Syrup and Sugar.—Landmann applies to 100 kilogrammes (220 lbs.) of carefully washed potato-starch from 350 to 400 kilogrammes (770 to 880 lbs.) of water and 10 kilogrammes (22 lbs.) of concentrated sulphuric acid (an enormous quantity). The acid is added to the

* Mostly in a great deal less time.—*Hutter.*

water, the mixture kept at a boil, and the starch milk is added in small portions, and thereupon boiled so long that a solution of iodide of potassium (to which a little muriatic acid or nitric acid has been added) no longer produces a blue or a brownish-red color. *Landmann* considers this juncture the point when the formation of sugar is completed to such a degree that all the dextrine has become transformed into sugar. (This opinion must however be regarded as erroneous.) The sulphuric acid is neutralized with lime; the liquid, freed of gypsum, is treated with three parts of refined animal charcoal, and thereupon evaporated to the consistency of syrup.

Landmann's process, however, is never applied, and possesses merely an historical interest.

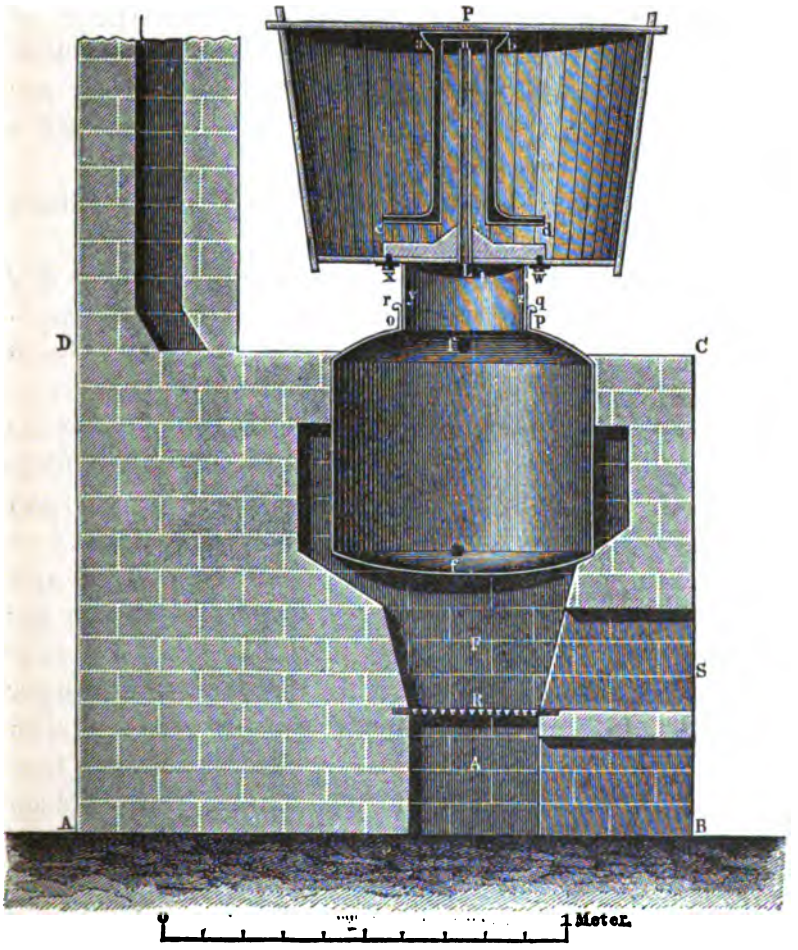
Rössling and Reichardt's Apparatus for the Manufacture of Glucose.—Rössling and Reichardt have constructed an apparatus for the manufacture of glucose and grape-sugar, which is still of interest at this time, on account of its successful application in producing glucose on a smaller scale.

The construction of this apparatus in a vertical section, is delineated in Fig. 38. *S* is the furnace opening, *F* the fireplace, *R* the grate, *x*, *y* and *w*, *z* the mechanism for the support of the barrel, consisting of a ring-plate and pipe. *x*, *w* are screws for the air-tight fastening of the barrel. *A* the ashpit, *f*, *f* apertures with pipes and cocks, *o p q r* the neck of the boiler.

P represents the barrel of white pine-wood, with a bottom of at least 2.5 to 3 centimetres (0.985 to 1.18 inch) thick. *L*, *H* a tube made of linden or maple-wood, 5 centimetres (1.97) inch thick and 2 centimetres (0.787) inch wide. *a b c d* is a pipe with four steam outlets below, two of which are visible at *c* and *d*.

The surface of the liquid in the steam-vats must compare to that in the boiler as 6 to 5. In the repre-

Fig. 38.



Rössling and Reichardt's apparatus.

sentation (Fig. 38), the dimensions are taken in such a way that 20 kilogrammes (44 lbs.) of starch can be operated upon at once.

Anthon's Method of Manufacturing Grape-sugar.—The most excellent grape-sugar is furnished by the method invented by E. F. Anthon, and his process of manufacture, as well as his mechanical appliances, have been patented in many countries. Anthon, who is the founder of this important branch of industry in Austria, has organized several large concerns, which work according to his method, and with the best success, a proof of the excellence thereof.

The manipulation itself—according to the inventor's own description—is as follows:—

The Boiling of 1200 *kilogrammes* (2640 *lbs.*) *of dry starch and* 2000 *kilogrammes* (4400 *lbs.*) *of green starch.*—1. *Boiling.* 1200 kilogrammes (2640 lbs.) of dry starch are stirred up in 1400 kilogrammes (1.4 cubic metres = 14 hectolitres = 370 galls.) of water to a homogeneous milk, and thereupon run into the converter in a uniform stream. The converter must previously be charged with a mixture of 200 kilogrammes (= 2 hectolitres = 52.8 galls.) of water with 48 lbs. of oil of vitriol, and brought to the boiling-point. The steam jet and the streaming in of the milk should be so regulated that the mass continues to boil uninterruptedly. In order to attain this end during the winter season, the starch may be stirred with tepid water, but not so warm that the starch becomes pasty. The adding of the starch is to be so regulated, that within the course of one hour the entire starch-milk has been emptied into the boiling vessel. Stirring is unnecessary, but the steam is regulated so that the mass steadily boils. The starch-milk in the stirring tank must be kept constantly in motion, to avoid a settling of the same upon the bottom. When the mixture has been kept at a boil for about one hour, after the entire mass has been

emptied into the boiling vat, the boiling is continued from four to five hours longer. This length of time is required for making the hard crystallized sugar, but when syrup is intended, or better, when the final aim is to obtain glucose, a three hours' boiling is sufficient. But the boiling is now kept up but gently, and for this purpose a small amount of steam is sufficient.

2. *Neutralization.* After the mixture has been kept at a boil from five and a half to six hours (from the time of the pouring in of the starch-milk), the process of neutralizing commences; for this purpose 30 kilogrammes (66 lbs.) of good boneblack, and 25 to 30 kilogrammes (55 to 66 lbs.) of purified chalk are used. The chalk must previously be mixed in water and strained through a fine sieve.

At first, 10 kilogrammes (22 lbs.) of boneblack are gradually thrown into the boiling mass, and then the chalk-milk is poured in through a leaden pipe, which reaches down to the lower half of the boiling vat. But great care must be taken that the seething liquid does not flow over the rim of the boiling vessel.

Having added a sufficient amount of chalk so that the mixture reacts but moderately sour, and hence litmus paper will be colored merely a slight violet, the adding of chalk is interrupted, and the balance of 20 kg. (44 lbs.) of boneblack is now added. The quantity of boneblack can be increased or decreased according to need. But it should be made a rule that one-third of the boneblack is to be added before throwing in the chalk, and two-thirds afterwards.

After finishing the process of neutralization the mixture is allowed to boil gently for about ten minutes, and is then passed through a *Taylor filter* of linen bags. All having run out of the converter it is then washed

out with some water, and this also left to run into the bags. When nearly all liquor has run through them, and the substance remaining in them is a thick paste, then it is carefully edulcorated with water until the liquor drained off indicates but from 2° to 4° B. The first part of the liquor running off has to be almost colorless and clear, and while yet warm indicate about 16° B.

3. *Evaporation.* The thin liquor is evaporated at once. In case common coagulated sugar is to be produced, it is to be condensed to 33° or 36° B. (weighed while hot); but if hard crystallized sugar is aimed at it must weigh about 33° B. (weighed hot). The syrup obtained by the former method is then passed through a small Taylor filter of flannel bags. The syrup thus obtained is now left to cool off. This is performed either in small coolers, or in small wooden tanks lined with zinc or copper.

After cooling off, a few kilogrammes (kg = 2.2 lbs.) of half-congealed sugar of a former boiling are added and thoroughly stirred in. After the lapse of from ten to twenty hours the mass will have become so stiff that (for the production of common sugar) it can be put into barrels, boxes, etc., and left therein to completely harden. The more of the granulated sugar that has been stirred in, and the syrup been beaten, the more uniform the sugar coagulates.

In the production of hard-crystallizing sugar, the effort should not be to cause a quick congelation, but on the contrary, the endeavor should be to keep the mass soft. To this end the evaporation is stopped at 33° B., the stirring should not be so strong, and not so repeatedly conducted, when the partly coagulated sugar is being added. Whenever in this latter case

the body of the sugar has attained a completely stiff consistency, so that it can only be scooped out with difficulty, it is then to be subjected to—

4. *Pressure.* For this operation cloths of coarse, solid gray linen and ordinary iron pressing-plates of 47 to 53 centimetres (18.5 to 20.9 inches) square are applied. The placing in of the paste is performed by first laying a wooden frame upon the plate. This frame is to be 4 centimetres (1.57 inches) high, and measuring from 44 to 49 centimetres (17.3 to 19.3 inches) in the clear. A press-cloth is then folded crosswise, and spread over it, and the sugar-paste put thereon. The paste is spread uniformly, and the folds of the cloth are joined together, the frame is lifted off, another plate placed upon it, etc., until the space in the press is filled up.

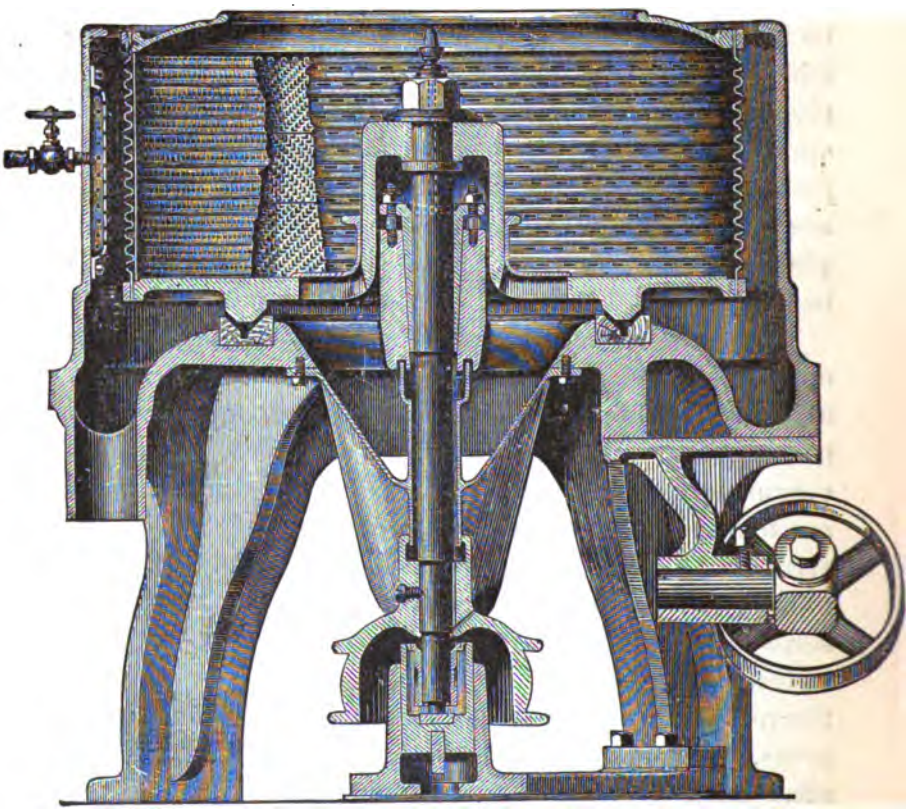
The press is then very gradually drawn together so as to avoid the tearing of the cloths. When finally, after the tightest pressing, no more syrup flows off, then the pressing is considered as ended. For this operation hydraulic presses or powerful screw presses are used. At all events, the presses should be so constructed that the frame be as high as possible (1.75 metres = 5.74 feet) so that a giving away of the inserted mass becomes impossible. It is best to press twice, first in a less powerful press, and thereupon after the readjusting of the plates, in a very powerful second press. The press-cakes, when taken out of the cloths after such a treatment, are composed of such pure sugar that the same may be used at once for the purpose of improving wines and cordials, and especially for confectionery, etc.

The most practical way of getting rid of the syrup is to use the centrifugal machine. Half the labor is

thus only required, and a better result obtained in less time.

Of all the different kinds of such machines now in use we have found those made by H. W. Lafferty, Gloucester, N. J., the best suited for the purpose. The following figure (39) gives a view of a vertical section

Fig. 39.



H. W. Lafferty's centrifugal machine.
(Vertical section.)

of their apparatus, showing the construction of the same, while the next figure (40) shows a set of four of their centrifugals. With a speed of from 800 to 900

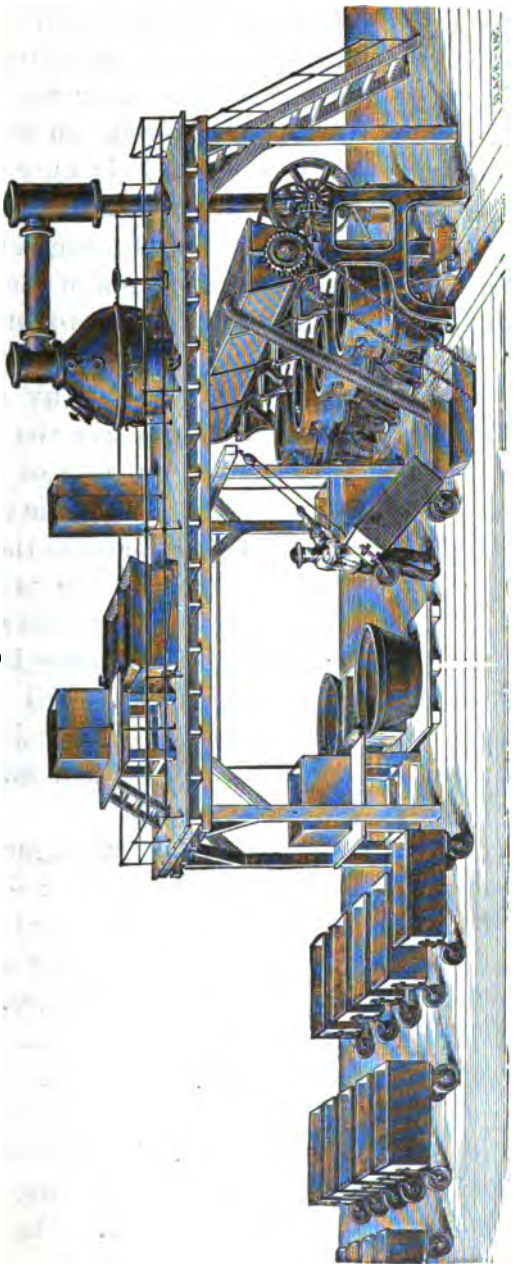


Fig. 40.

Set of four centrifugals, arranged for open train with vacuum pan. H. W. Lafferty, Gloucester, N. J.

revolutions per minute such a machine will do as much work in a given time as any other machine, effect a saving of power, and reduce the wear and tear and danger consequent upon higher speed. In discharging the dry sugar from this machine it is only necessary to raise a valve in the centre of the basket, and cut the sugar from the sides. It then falls through an opening into a receptacle below and at the back of the machine. Another improvement is the brake for stopping, which is operated by the same lever that is used for starting, by raising or lowering the basket. Any floor of a factory possessing the stability to carry the weight of the machine will answer for the purpose of a bed, no shaking or jarring being noticed during the rotation of the basket. This house also manufactures the raw and refined starch centrifugals now so much preferred to the use of the inclined plane—bringing forth six square cakes which are very dry, and may at once be brought into the drying-rooms for the finish. All those acquainted with the slow process of the inclined plane and the so-called finishing troughs, will find them a great and meritorious improvement.

If it should be desired to make loaf-sugar, then the following manipulation must be observed:—

5. *Remelting.* The press-cakes or sugar taken from the centrifugal basket are broken up into small pieces and melted, but without adding any water. This is done in a kettle which is more flat than deep, and not over an open fire, but over a steam-bath. The melting is aided by an occasional gentle stirring in a temperature as low as is possible. The heating is continued until all lumps have become crumbled up, but not until the fine parts are dissolved. For 400 kilogrammes (880 lbs.) of sugar this melting operation

requires from three to four hours' time. A complete dissolving of the sugar must be at all times avoided, since those parts of sugar which finally float in the solution, are the means of the ensuing of a nice crystallization. When the sugar thereupon has passed into the solution, in the manner set forth, the temperature at this juncture being about 70° to 80° C. (158° to 176° F.), the mass, having attained the proper consistency, is then cast into the moulds. After two days' rest the sugar is entirely solid, and is removed from the moulds.

6. *Utilization of the pressed-out Syrup.* Of 100 kilogrammes (220.lbs.) of dry starch, 57 klgr. (125.4 lbs.) press-cake are obtained, and about 50 klgr. (110 lbs.) of press-syrup. This syrup can either be mixed with such syrup as contains a large amount of dextrine, and sold as such, or boiled and worked over again so as to make a second product of press-cakes. To this end it is evaporated to from 36° to 37° B. (weighed while hot), permitting it to cool off and to coagulate as described heretofore; whereupon it is likewise pressed out. The press-cakes thus obtained furnish a less handsome article, and it is best to dispose of the press-syrups as such.

7. *By the aid of Sulphurous Acid.* In order to obtain a product of the whitest possible color, the application of sulphurous acid has been frequently mentioned. This acid is manipulated thus: after half of the requisite quantity of chalk has been applied during the process of neutralization, the further adding of chalk is interrupted, and placing into the boiling vat either 1.5 or 2 kilogrammes (3.3 or 4.4 lbs.) of dry, or 5 kilogrammes (11 lbs.) of liquid sulphite of lime; continuing the boiling for ten minutes, and thereupon adding the rest of the chalk. In conclu-

sion, it may be remarked, that it is imperative to carry out the process with great cleanliness, and to use no other water but such as contains no *hygroscopic* ingredients, and none which will be turned brown by sulphuric acid.

The sugar obtained by this process is hard and white like loaf sugar, and porous, but of course does not possess the transparent crystalline appearance, but looks dull and whitish. It contains 95.3 per cent. of anhydrous starch-sugar and 4.7 per cent. of water. Its contents of water, therefore, do not exceed two equivalents (10 per cent.), as is the case with common hard starch-sugar, but only one equivalent (5 per cent.). It corresponds to the formula, $C_{12}H_{12}O_{12}+HO$, while the common starch-sugar corresponds to $C_{12}H_{12}O_{12}+2HO$.

Anthon's Latest Improvements for the Manufacture of Smaller Quantities. His Perfected Machinery.

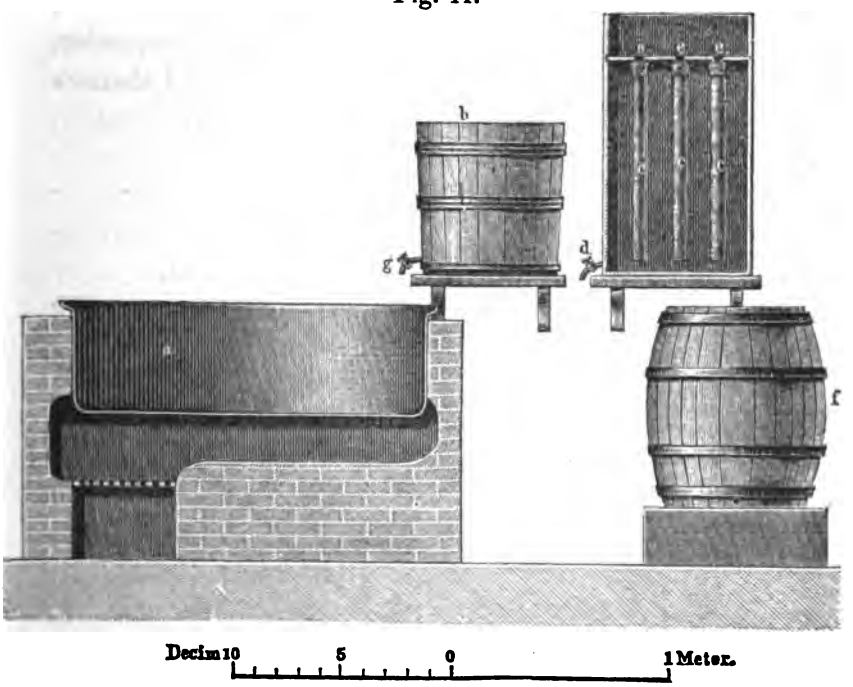
I. *The Method of producing from* 160 *to* 200 *kilogrammes* (352 *to* 440 *lbs.*) *of Glucose, within twenty-four hours.*—Proportion of the material to be mixed for a boiling:—

168	kilogrammes	(370 lbs.) of air-dry starch.
5	"	(11 ") of sulphuric acid of 66° B.
1.68	"	(3.70 ") of bone-black.
1.12 to 1.68	"	(2.46 to 3.70 lbs.) of pure burned lime.
2.25	"	(4.95 lbs.) of prepared chalk.

II. *Fitting up of the Apparatus.*—The machinery which Anthon applies for this method is very simple, and is represented in Fig. 41; *a* is the pan, *b* a vat of about 3 hectolitres (8.4 bushels) capacity with a

wooden spigot *g* affixed at the bottom; *c* Taylor's bag-filter placed in a closet-like case. This case is 1.25 metres (4.1 feet) high and 64 centimetres (25.2 inches) wide, and deep (square). It is arranged for the reception of nine bags, each of about 80 centimetres (2.6 feet) in length, and of 15 to 18 centimetres (5.9 to 7 inches) diameter, when it is filled. This filter-closet must be set up in such a manner that the thin liquor can be drawn off by a small gutter, not only into the tank *f*, but also directly into the pan *d*.

Fig. 41.



Anthon's perfected machinery for the manufacture of grape-sugar on a small scale.

The bags for this filter are to be made of gray linen of a prime quality and of uniform weft. These bags must be fastened over the funnels *e e e*, with strong cord.

f. Barrel of about 3 *to* 3.5 *hectolitres* (8.4 *to* 9.8 *bus.*) *capacity, for receiving the filtered thin juice.* A very small Taylor filter is furthermore required. The same should also be encased with wood, and contain a space for but six bags, of 56 centimetres (1.83 feet) length, and from 13 to 15 centimetres (5.1 to 5.9 inches) in diameter (when filled up).

The entire height of this closet is to be 8 centimetres (3.15 inches), its depth 37 centimetres (1.2 feet), and its width 53 centimetres (1.74 feet). The filter contains double bags; the outer of coarse gray linen, serving for the purpose of supporting the inserted flannel bags. The latter must be made somewhat larger, than those of linen, because the flannel shrinks by exposure to the heat, and these flannel bags should, even after having shrunk, be still somewhat larger than those made of linen. Finally a wooden tank for the finished sugar is required. This tank should be lined throughout with very thin copper sheets.

III. *Manipulation.*—At six o'clock in the morning 168 kilogrammes (369.6 lbs.) of water (measured) are placed in the previously scoured pan *a*, and from 168 to 196 kilogrammes (369.6 to 431.2 lbs.) of water in the vat *b*. A fire is kindled under the pan, and while constantly stirring 168 kilogrammes (369.6 lbs.) of starch are put in the vat *b*. Before this, while yet the water in the pan *a* is cold, 1.68 kilogrammes (3.69 lbs.) of sulphuric acid are slowly and cautiously added, while stirring. The acid however, may previously be diluted in 3.36 kilogrammes (7.39 lbs.) of water. This is done in a vessel lined with thin lead; and it can then be poured in at once.

If a heated room is adjacent, it would be well, especially in winter, to allow the starch to stand for a few

days, in order to warm it through. It is also best, if the water which is to be poured into the starch-stirring vats, has a temperature of 50° C. (122° F.). When the acid-water in *a* is at a full boil, and the starch in *b* is uniformly stirred up, then the latter is permitted to flow through the cock *g* in a small jet towards *a*. During this operation, the stirring must not cease, and the liquid must be kept at a constant boil; and paste formation is to be carefully avoided. When all the starch-milk has run into the pan (this should be accomcomplished by 8 A. M), the further stirring may be stopped, and the mixture must be allowed to keep on gently boiling.

This boiling is to be continued from five to seven hours,* or at least so long until a little sample of the liquor, into which some alcohol is dropped, will no longer produce a milky and turbid sediment. The evaporating water is to be replaced by fresh water during the process. If the liquid should be condensed by this process to above 20° B., then the evaporated water should be renewed by a fresh supply, or what is still better, by adding some of the drained-off water of a former boiling. As soon as the alcoholic test no longer shows a milky sediment, the fire is gradually diminished, and now the process of neutralization begins. To this end, 2.25 kilogrammes (4.95 lbs.) of lime have been slaked on the preceding day, and being mixed into a milky substance, and strained through a small, narrow wire sieve, are thus in a fine jet poured into the pan, while a rapid stirring is maintained. Thereupon a mixture of 1.68 kilogrammes (3.7 lbs.) of prepared chalk in 3.36 kilogrammes (7.39 lbs.) of water

* When glucose is to be the final resul', only three hours.

(which has also previously passed through a wire sieve) are added, until no more effervescence occurs, and a piece of blue litmus paper is yet colored red, whereupon finally 1.68 kilogrammes (3.7 lbs.) of bone-black dust are stirred in. Thereupon the entire contents of the pan are brought into the somewhat moist bags of the filter, but the cooling off of the liquid must always be avoided in this operation, as much as is possible. The first part of the drained off substance being somewhat turbid or dull is always returned to the filter. The substance should be equally distributed in all the bags, as this will tend materially to lessen the work of the process of edulcoration. The pan being empty, is washed out with pure water, and this water added to the liquor in the filter, and then the substance in the bags is completely edulcorated by applying pure, fresh water. As soon as the liquor issues much weaker (about 10° B.) it is no longer allowed to run towards *f*, but it is collected in various portions (according as its density decreases) to be added to the mixture of a subsequent boiling.

The emptying and washing out of the pan should be hastened, in order at once to place the yet heated and filtered thin liquor in the same, and to evaporate it quickly, by keeping up a brisk fire. At this juncture the thin liquor of the filter is no longer permitted to flow towards *f*, but to run directly into the pan, as long as the liquor indicates more than from 10° to 12° B., whereupon it is, as already mentioned, to be collected in portions. As soon as all the thin liquor is in the pan, the boiling is continued, until it indicates a density of 32° to 35° B. (weighed while hot), the fire is then removed, the syrup placed on the

flannel filters, and it can be used at once, after cooling off.

The drawing off from the pan must be attended to with great care, so that it be cooled off, as well as the brickwork, so that by the time of its nearly complete emptying, the remainder of the sugar solution will not begin to burn. As soon as the glucose solution is filtered off from the flannel bags, the pan is washed out with some thin liquor and water, and this liquid is poured into the filter-bags, and these latter are allowed to hang overnight undisturbed. On the following day the contents of these bags are emptied into the pan, after another conversion has been made and finished after the neutralizing of this second boiling.

The connecting channel from the fireplace of the pan to the chimney is to be established in the shortest possible way, and in a straight line. A door for cleaning purposes should be likewise attached.

In the left corner of the pan, an elbow-pipe, about 15 centimetres (5.9 inches) in width, and supplied with a damper, is inserted, whereby a direct connection is maintained between the actual fireplace and the chimney, in order to avoid the driving back of the smoke, while the fire is being kindled.

The pan must always be kept clean and well scoured, and should be covered with a lid of wood, in which an opening of from 14 to 16 centimetres (5.5 to 6.3 inches) square is made; at all events it should be large enough to allow the insertion of a light wooden chimney, which extends above the roof of the establishment for the escape of the steam.

The Production of Capillair Syrup and Sugar.— Some few establishments have furnished quite recently an absolutely water-clear syrup, which in a very con-

densed state is known in the market by the designation of capillair-syrup.*

The *modus operandi* for producing this brilliant glucose is as follows:—

After the starch has been boiled in the usual manner for procuring a syrupy article, and after the process of neutralization is finished, the clear, thin liquor of from 16° to 20° B. thus obtained is condensed in a vacuum pan to 30° B. (weighed while boiling hot). The vacuum pan should be of copper, because by this process of evaporating the liquor the gypsum will deposit itself on the copper pipes as firmly as stone, and hence the pipes, by aid of muriatic acid, have to be frequently cleaned.

If the temperature in the vacuum can be maintained at 57°.5 to 63.75° C. (135.5° to 146.75° F.) the syrup will remain so much the lighter. The time occupied by the process of evaporation also influences the color of the article. The more rapidly the evaporation ensues the lighter the syrup will be. This syrup has not to be clarified by settling, and this method is yet maintained in some manufactories. But inasmuch as the settling of the liquor occupies a long time, and since the gypsum never completely separates from this already somewhat heavy syrup, the filter-presses are used for this operation to great advantage. Thus the clarifying process is much accelerated, and the thin syrup issues from the filter presses free from gypsum, and entirely clear.

From the filter press the syrup is directly pumped into the reservoir, and from thence to the boneblack filter.

* This glucose is the article used so extensively by the confectioners and others in the United States.—*Hutter.*

These filters are to be from 3 to 3.5 metres (9.8 to 11.5 feet) high, and of a diameter of .75 metre (2.5 feet). The syrup must pass slowly through the filters, and the first part of the filtered liquor, being of yellowish and muddy color, is again placed in the reservoir, from whence it is again pumped on to the filter.

The filtered liquor is now sucked into the vacuum pan, and evaporated at a temperature of from 56.5° to 62.5° C. (133.7° to 144.5° F.). If the syrup is to be used for exportation the condensation is to be = 44° B. (weighed at 61° to 62.5° C. = 141.8° to 144.5° F.). The process of evaporation goes on very quickly, since the syrup already possesses a consistency of from 28° to 30° B. before it enters the vacuum, so that from 10 to 15 kilogrammes (22 to 33 lbs.) of syrup can be finished within one and a half hours.*

The capillair-syrup for the export trade has to be filled into the casks while yet lukewarm. If it cools off entirely it will not run out of the vats at all, or so sluggishly that it would occupy a great deal of time.

The perfectly white and finest quality of grape-sugar, which also passes through the boneblack filters, is known as *capillair grape-sugar*, and is manipulated in a similar way to that for the production of syrup, with this difference, viz., that the syrup at the last stage is condensed from 44° to 45° B., while for the production of sugar, the process of evaporating must be stopped as soon as the syrup has reached the consistency of from 40° to 41° B.

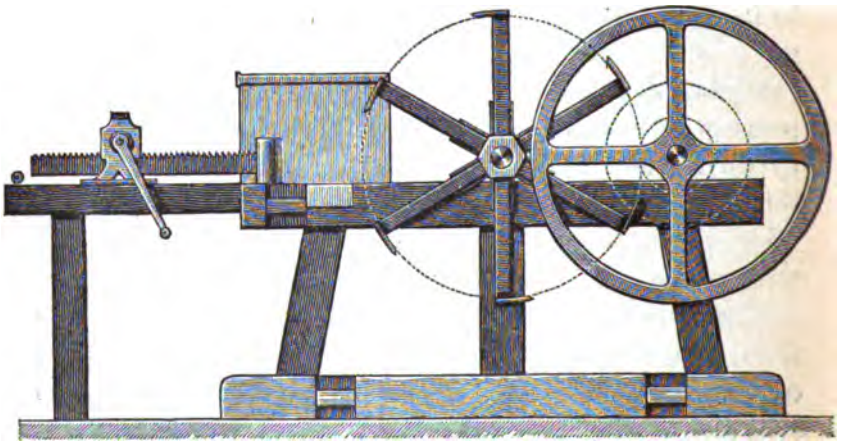
This sugar has heretofore been mostly packed up in cases of 50 kilogrammes (110 lbs.), and has thus been introduced into the market. But more recently the

* But by the use of the improved vacuum pump much faster.

sugar has been cast into blocks and loaves, and these are afterwards grated, and the sugar then packed in bags.

The construction of a very excellent sugar-grating machine is delineated in Fig. 42, and requires no further description.

Fig. 42.



Sugar-grating machine.

This modern method of packing the sugar in bags or sacks is far more practical and advantageous than the older method of packing it in boxes, since the sugar adheres to the wood of the boxes, is hard to loosen from the sides of the cases, and hence much is irretrievably lost.

Granulated Starch-sugar. — The manufacture of granulated grape- or starch-sugar was introduced by Fouchard at Neuilly, France. The transformation of the starch into sugar is accomplished in the same manner as has already been described, and of course at an increased temperature and greater atmospheric

pressure, inasmuch as a greater amount of dextrine would be a hindrance to the granulation of the sugar.

The liquor being saturated with lime is caused to run through a boneblack filter in order to impart to it the color of a nice clear *covering* sugar.* The filtered liquor is thereupon evaporated either by the application of *Roberts's* apparatus or in the vacuum pan. This manipulation is done in summer by condensing to 30° B., in winter to 28° B. (weighed while boiling). The syrup is then run into capacious clearing tanks, where the greater part of the precipitated gypsum settles. These tanks must be placed in a cool location, or the cooling process is accelerated by the use of worms in which cold water circulates, so as to avoid fermentation. After the lapse of from twenty-four to thirty hours the syrup is cool and clear, and is then placed in vertical barrels, which are left open above, and whose bottoms are perforated with small holes, thus forming a sieve bottom. During the process of crystallization these openings are kept closed with small wooden pegs or taps. The barrels stand on the traverse joists of a frame-work which is only 30 centimetres (11.8 inches) high, over a gutter lined with lead.

In the course of from ten to twelve days the crystal-

* In order to hasten the bleaching of the glucose during the process of its manufacture the following treatment should be observed: Mix 10 kilogrammes (22 lbs.) of boneblack in 50 kilogrammes (110 lbs.) of sulphuric acid, macerating the mixture from twelve to fifteen hours, stirring it, and pouring the same into the vessel in which the transformation of the starch into sugar is taking place. To each portion of sulphuric acid thus applied boneblack is added in the manner prescribed. By this method the starch-syrup is at once bleached.

lization begins by the formation of small accumulations in the syrup, which gradually increase. As soon as the syrup is about two-thirds filled with crystals, the holes in the bottom of the barrels are to be opened, draining off the molasses, while the soft crystalline accumulations remain in the barrels. If the crystals appear in such a crowded state, that the dropping off of the molasses does not ensue freely, it should be diluted with a small portion of water.

As soon as the draining off appears to be finished, this operation is perfected by placing the barrels in an inclined position (45°). The molasses thus obtained is to be again boiled in sulphuric acid water, in order to transform the dextrine contained therein into sugar.*

The granulated sugar thus obtained is then placed on gypsum slabs to the height of 10 centimetres (3.9 inches) and dried in a temperature of from 22° to 25° C. (71.6° to 77° F.). By increasing the temperature for this purpose, the crystals would melt in the latent syrup and stick together. However, this occurrence (the lump formation) cannot be entirely avoided, despite all the possible care which may be observed. If it should be noticed that the lower part of the layer begins to become dry and white, it is to be turned, so that the upper part is placed below and experiences the same change.

In the course of three or four days the sugar becomes perfectly dry, and is then, for the purpose of an even separation, ground through a sieve, while the lumps which do not pass through the sieve are ground between a pair of porcupine rollers. Usually the sugar is thereupon again spread on gypsum slabs.

* See also method of centrifuging, previously described.

Fouchard's granulated starch-sugar forms loose grains, each of them consisting of a mass of small rhomboidal tablets, grouped around a common centre. This sugar is very similar to our granulated cane-sugar, and is frequently used in adulterating it.

The Manufacture of Grape-syrup and Grape-sugar from Grapes and Raisins.—For the production of grape-sugar from grapes, it is best to use the perfectly ripe fruit of the white species, pressing the same in any suitable manner. The *must* thus obtained is heated and mixed with finely ground terra-alba, witherite, or chalk, in order to neutralize a part of its tartaric acid. Thereupon the liquid is heated to boiling, then left to rest for 24 hours, in order to allow the precipitation of the insoluble salts which have formed.

The *must*, having to a great extent thus been freed of its acid, is now cleared by the application of from two to three per cent. of its volume of ox-blood or albumen, skimmed, and finally evaporated down to 26° B. The syrup thus obtained is, however, not yet perfectly pure, but still contains mucilaginous ingredients, which may be most suitably removed by a prolonged depositing. In order to accomplish this, the grape-syrup is deposited in large tanks, and left at rest for some time, until the impurities settle to the bottom. By means of a careful drawing off of the now perfectly cleared liquid, and by evaporating the same down to 34° B., a grape-syrup is obtained, which is entirely applicable for most of the purposes for which the various starch-sugars are used. For improving wines and apple-cider such syrup excels all others, but is generally too expensive.

Of this grape-syrup, solid sugar can also be made, by placing the thickly condensed syrup in crystallizing

vessels, wherein after the lapse of from three to four weeks granulated crystals will become separated. The non-crystallizable fruit, or mucilaginous sugar, is thereupon removed by means of a pure starch-sugar solution, which is poured into the forms which contain the crystallized grape-sugar. The same object can also be attained by means of the centrifugal apparatus.

If real grape-sugar is produced in very small quantities, the removal of the non-crystallizable mucilaginous sugar can be attained by pouring the moist paste upon large clay slabs, over which filter-paper has been spread.

The yield of grape-sugar from grapes, as is self-evident, varies greatly according to the quality of the grapes. On an average it may be accepted, that the yield will result thus:—

From 1000 parts (weighed) fresh grapes.
800 " of must.
200 " of syrup.
140 " of crude grape-sugar.
60–70 " of pure grape-sugar.

The Quality of Starch-sugar. Determination as to Impurities and Adulterations of Starch-sugar.

Grape or starch-sugar in its pure state is hard and white like loaf-sugar, more or less porous, and possesses withal a peculiarly dull, not transparent appearance. Anthon's granulated sugar, known to be the best in commerce, contains 95.3 per cent. of anhydrous starch-sugar and 4.7 per cent. of water. Its contents of water amount therefore to but one equivalent and not=two equivalents (10 weight per cent. of water), as is the case with common sugar. Grape-sugar

makes its appearance but seldom in the trade in a pure state, is often not even sufficiently dry, but possesses a greasy almost soap-like consistency, is more or less of a yellowish or brownish color on account of its foreign admixtures, and hence does not furnish a transparent solution.

The chemist *C. Newbauer* analyzed a series of grape-sugar samples from various manufacturing establishments, with the following result. Above all he observed, that most of the sugars which he tested could hardly claim the title of grape-sugars, by which they are known. Many of these articles were not even dry, but had a soap-like feel and consistency; many were not even colorless, and all of them without exception failed to dissolve *clear* in alcohol. All of the specimens investigated, even the most nearly colorless samples of grape-sugar, showed a more or less turbid liquor, when dissolved in but little water and this mixed with strong alcohol; all this originated from the dextrine yet remaining in the product, the latter being an intermediate product between dextrine and sugar, with an admixture of gypsum. Solutions of 10° B. of these preparations, when placed in test-tubes with capillary closure, and left exposed to the air, developed very strong fungi vegetations, while solutious of crystallized, pure cane-sugar, even after the lapse of months, showed scarcely any traces of fungi when placed under the microscope. All of the above mentioned moist preparations of soapy consistency—and they are not unfrequent in the trade—are inclined to become mouldy and musty. In closed glass jars, some pieces soon become covered with fungi, and on the opening of the jars a most nauseating smell was noticed.

Dr. Neubauer does however by no means assert, that all the grape-sugar of commerce, is to be found in such a deplorable condition, but many of the specimens investigated by him were of that inferior nature. In the following table the results of the test of thirteen different samples of grape-sugar are given :—

	Sp. gr. of the solution of 100 g. (3.5 ozs. av.) to the litre.	Dry substance, according to Balling. Per cent.	Dry substance in starch-sugar. Per cent.	Non-fermentable substances. Per cent.	Fermentable starch-sugar. Per cent.	Water. Per cent.
1	1.0306	7.609	78.42	21.18	57.24	21.58
2	1.0340	8.438	87.25	23.47	63.78	12.75
3	1.0300	7.463	76.87	20.67	56.20	23.13
4	1.0340	8.438	87.25	23.47	63.78	12.75
5	1.0323	8.024	82.84	23.59	59.25	17.16
6	1.0325	8.073	83.36	19.90	63.45	16.65
7	1.0327	8.122	83.88	22.45	61.43	16.12
8	1.0336	8.341	86.21	21.43	64.78	13.79
9	1.0329	8.170	84.39	20.29	64.10	15.61
10	1.0298	7.413	76.34	18.32	63.02	23.66
11	1.0464	11.428	79.72	20.58	59.14	20.28
12	1.0325	8.073	83.36	22.70	60.66	16.64
13	1.0295	7.341	75.58	18.23	57.20	24.42

The mean composition is :—

Fermentable grape sugar . . .	61.08 per cent.
Non-fermentable substances . .	20.88 "
Water	18.04 "
	100.00 per cent.

E. Schmid found by his investigations of six different kinds of grape-sugar, 86.6 per cent. dry substance and but 13.4 per cent. of water. In the mean these grape-sugar samples furnished :—

Fermentable sugar	70.1 per cent.
Unfermentable substances . . .	16.5 "
Water	13.4 "
	100.00 per cent.

Fred Mohr, who investigated six different kinds of grape-sugar, according to Anthon's method, found in

these from 9 to 45 per cent. of impurities. In two tests of fermentation, which were made with 25 per cent. solutions of pure starch-sugar of Anthon's make, and of commercial sugar, the indicator of the saccharometer sank to 1.05, in the case the first mentioned, hence a complete fermentation had ensued in this case, while in the case of the commercial grape-sugar, after the finished fermentation, the saccahrometer still showed 9.5 per cent. of non-fermentable substances. *Fred. Mohr*, who is otherwise a supporter of Gall's method, came to the conclusion that most of the grape-sugar of commerce "is naught else but trash." In the mean the composition of grape-sugar is determined according to Mohr's test:—

Fermentable sugar	60.65 per cent.
Non-fermentable substances . .	24.00 "
Water	16.00 "
	100.65 per cent.

The glucose manufacturers—so thinks Mohr—seem to have no cause for improving their article and making progress in the manufacture of their sugar "as long as with from 16 to 20 per cent. non-fermentable substances, they still find consumers enough."

The least reliable results as to the true amount of sugar in commercial starch-sugar, are furnished by the optical test, when carried out by means of one of the known "*polarization apparatus.*" For all practical purposes, the testing of grape-sugar, as to its contents of real sugar, is most frequently accomplished, by finding out the specific gravity of a saturated solution at 15° C. (59° F.), according to Anthon's method. For this purpose 75 grammes (2.62 ozs. avoird.) of the sugar to be tested, are first accurately weighed and

then put in a cylinder glass, adding thereto 75 grammes of distilled or rain-water, or otherwise very pure water, thereupon leaving this mixture to stand for two days, but shaking and stirring it frequently. Thereupon a so-called 0.1 litre (3.38 flu. ozs.) flask is used, which is accurately measured and marked by a line at the point where it holds 0.1 litre = 10 centiliters (the flask holding generally something more than 10 centilitres), weighing it accurately and noting its weight. The temperature of the sugar solution is then accurately fixed at 15° C. (59° F.). Thereupon from the upper part of the sugar solution, which is almost entirely clear, exactly 0.1 litre = 10 centilitres (3.38 fluidozs.) are poured into the weighed flask, and now this flask is again accurately weighed with its contents. Deducting from the total weight the weight of the flask, the net weight is thus obtained, of exactly 0.1 litre (3.38 fluidozs.) or 10 centilitres of the sugar solution at a temperature of 15° C. (59° F.). If the weight of 0.1 litre (3 38 fluidozs.) of this solution is = 120.6 grammes (4.22 ozs. avd.), that is 20.6 grammes (317.9 grains) larger than 0.1 kilogramme (0.22 lb.), then the tested sugar will be entirely pure, that is, it contains of foreign ingredients 0 per cent. and so on, as can be seen by the tabular statements, prepared by Anthon.

Table for ascertaining the purity of Grape-Sugar according to the method of Anthon.

Specific grav. at 15° C. (59° F.) of the saturated sugar solution.	Amount of foreign ingredients in the starch-sugar. per cent.	Specific grav. at 15° C. (59° F.) of the saturated sugar solution.	Amount of foreign ingredients in the starch-sugar. per cent.	Specific grav. at 15° C. (59° F.) of the saturated sugar solution.	Amount of foreign ingredients in the starch-sugar. per cent.
1.2060	0	1.2368	16	1.2608	31
1.2082	1	1 2386	17	1.2618	32
1.2104	2	1.2404	18	1.2638	33
1.2125	3	1.2422	19	1.2649	34
1.2147	4	1.2440	20	1.2665	35
1.2169	5	1.2456	21	1.2680	36
1 2189	6	1.2473	22	1.2695	37
1.2208	7	1.2489	23	1.2710	38
1.2228	8	1.2506	24	1.2725	39
1.2247	9	1.2522	25	1.2740	40
1.2267	10	1.2535	26	1.2755	41
1.2284	11	1.2548	27	1.2770	42
1.2300	12	1.2561	28	1.2785	43
1.2317	13	1.2574	29	1.2800	44
1.2333	14	1.2587	30	1.2815	45
1.2350	15				

Anthon has thoroughly studied the subject of the solubility of grape-sugar in alcohol. His experiments made in this direction have resulted in establishing the fact, that the solubility of grape-sugar in alcohol is in the inverse ratio of the amount of water contained in the latter; and that a certain quantity of alcohol will dissolve so much less sugar, the more water the alcohol contains.

For the quantitative determination of grape-sugar, the great chemist, *Gentele*, has furnished directions, which rest on the following:—

a. That a solution of cane-sugar does not become decomposed by an aqueous solution composed of 1 part of ferrocyanide of potassium (red prussiate of potash) and 0.5 part of hydrate of potash either in a common temperature or by boiling, and that a very small quantity of this reagent will color the cane-sugar solution to a permanent strong yellow.

b. But that a solution of grape-sugar will slowly discolor the cited reagent in the cold, but more rapidly in a temperature between 50° and 60° C. (122° and 140° F.), and very quickly between 60° and 80° C. (140° and 176° F.), retaining this action as long as yet undecomposed grape-sugar is present. For a decomposition of that quantity of *Invert-sugar*, which results from treating 1000 milligrammes (15 grains) of cane-sugar with muriatic acid, 10,980 milligrammes (169.4 grains) of ferrocyanide of potash are necessary; hence 10.980 grammes (169.42 grains) of this salt for 1 gramme (15.43 grains) of cane-sugar.

c. That dextrine, no matter how produced, does not act upon the same reagent, even when this gum has been treated under the same conditions with muriatic acid, by which cane-sugar is *inverted* by this acid.

d. That in a solution of cane-sugar in its forty-fold weight of water, to which 25 per cent. concentrated muriatic acid, of the weight of the sugar, has been added—all of the cane-sugar passes over into "inverted sugar," when the same is heated over a water bath at a temperature of 54° or 55° C. (129°.2 to 131° F.). In order to apply these facts for the purposes of determination, a test liquid is prepared which contains in 100 cubic centimetres (3.38 fluidounces), 10.980 grammes (169.42 grains) red prussiate of potash, and 5.5 grammes (84.86 grains) hydrate of potash. Now to prove the presence of grape-sugar in cane-sugar, 1 gramme of the latter is dissolved in 40 cubic centimetres (10.8 fluidrachms) water, the solution heated to 70 C. (148° F.), and 0.1 cubic centimetre (.027 fluidrachms) added of the test liquid. If the color of the latter disappear right off, then a good deal of grape-sugar is present.

In conclusion, it may be deemed of interest to mention here, how to test the presence of grape-sugar in honey and manna when adulterated with that article. This can be easily determined from the fact, that since neither starch-sugar nor starch-syrup is ever entirely free from gypsum, and since honey and manna never contain even a trace of gypsum, hence the presence of the latter mineral furnishes ample proof of such an adulteration.

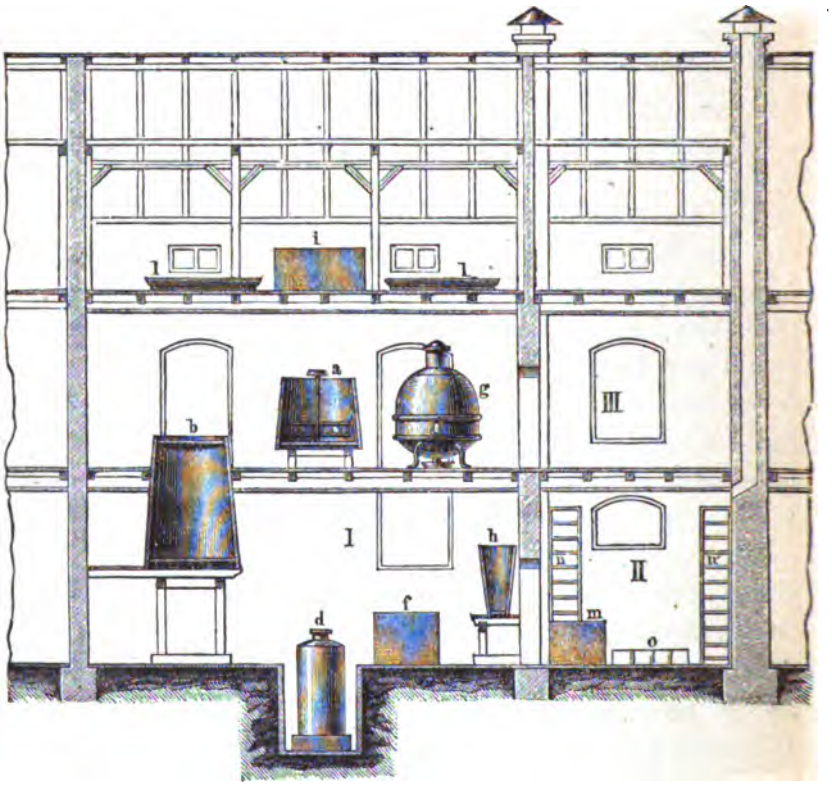
Application of Glucose and Grape-sugar.

The most important use for grape-sugar is found in the improvement of wines, for the purposes of *Gallizing* and *Petiotizing* them. Although there is no application known for which grape-sugar is used, that could not be equally as well accomplished by the use of common cane-sugar, yet since this article is far more expensive than the best grape-sugar, it is in the interest of the wine-growers to use the latter article, provided the grape-sugar be pure. *Gall* and *Petiot* have proposed to use for the improvement of wines exclusively, the so-called grape-sugar. In some countries, the syrup of glucose finds much application in the art of brewing beer, etc., for the distilling of ardent spirits, and as an admixture to honey and sugar-house syrups. It is also used in large quantities by confectioners and candy-manufacturers. For the preserving of fruits, and for the fabrication of fruit-syrups, etc., the article "imponderable syrup" serves its purpose well. And last but not least, grape-sugar furnishes the raw material for the production of "*sugar coloring*," an article used for imparting the brown color to cordials, liquors, wine, vinegar, rum, and cognac, and is also frequently ap-

plied to give *tone* to beer and other beverages of malt, etc.

Description of a Glucose and Starch-sugar Manufactory.—The following sketches (Figs. 43, 44, 45) represent a very suitable arrangement for the construction

Fig. 43.



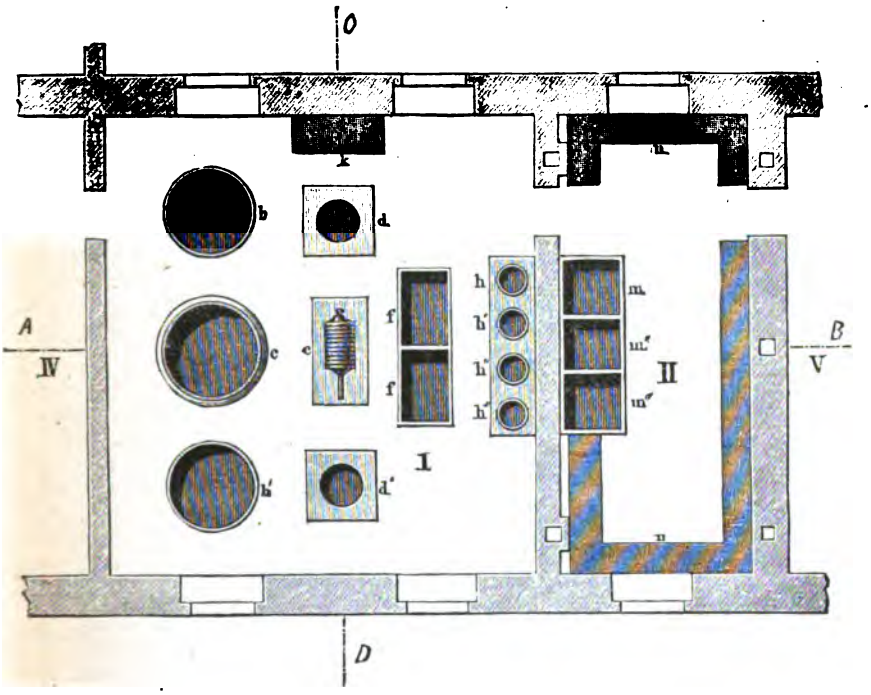
Glucose factory of Noback Bros. & Fritze, in Prague (Bohemia).

of a glucose manufactory, which in a comparatively limited space contains only the most indispensable apparatus and utensils, arranged in a highly practical manner.

I, is the boiler-house; *II*, the cooling-room; *III*,

the laboratory; *IV*, the potato-starch manufactory; and *V*, the warehouse.

Fig. 44.



Glucose factory of Noback Bros. & Fritze, in Prague (Bohemia).
Ground plan.

The inner appointments of this establishment consist of the following:—

a, starch-stirring vat; mean diameter 2 metres (6.56 feet); height 1.60 metre (5.25 feet).

b, two boiling-vats; mean diameter 2 metres (6.56 feet); height 3 metres (9.84 feet).

c, liquor reservoir; mean diameter 2.5 metres (8.20 feet); height 1.5 metre (4.92 feet).

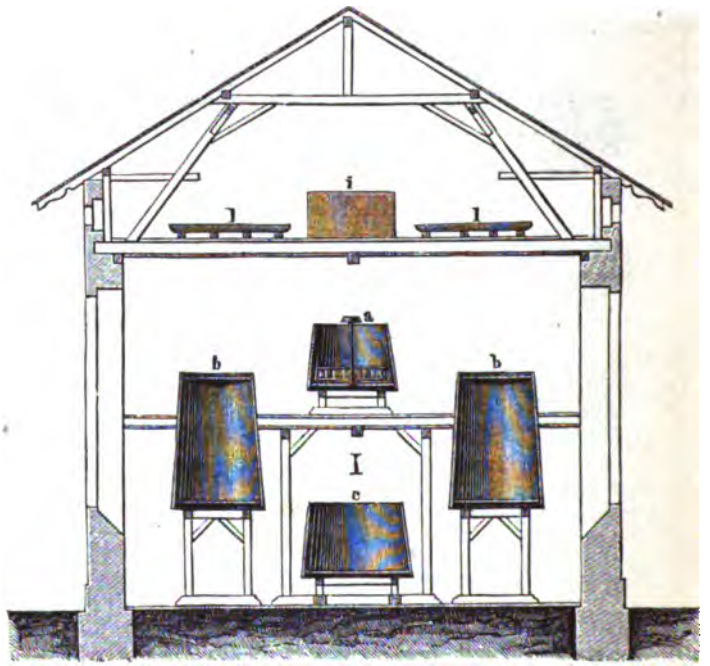
d, two Montejus, each having an automaton; diameter 0.80 metre (2.62 feet); height 2 metres (6.56 feet).

e, the steam filter-press.

f, two sugar-liquor reservoirs à $1 \times 2 \times 1\frac{1}{3}$ metre (3.28 × 6.56 × 4.92 feet).

g, vacuum pan, diameter 1.60 metre (5.25 feet).

Fig. 45.



Glucose factory of Noback Bros. & Fritze, in Prague (Bohemia).

h, four filters, 1.35 metre (4.43 feet) high; upper diameter 0.80 metre (2.62 feet); lower diameter 0.70 metre (2.3 feet).

i, water-reservoir.

k, air-pump.

l, two cooling-vats (bacs).

m, three coolers à $1\frac{1}{3} \times 1\frac{1}{3} \times 0.65$ metre (4.92 × 49.2 × 2.13 feet).

n, wooden closet 0.40 metre (1.31 feet) wide.

The grape-sugar products of commerce, whether in liquid or solid form of aggregation, contain hardly ever more than 60 per cent. of starch-sugar. The remainder is composed of water, dextrine, and of diverse intermediate products. Thus far there is but one exception to this general rule, namely, Anthon's crystallized starch-sugar. His product contains but one equivalent of water.

SECTION III.

THE MANUFACTURE OF SUGAR-COLOR (COULEUR).

By the designation *sugar-color*, or *couleur*, at present is known that article which formerly was termed *tincture of sugar*, a concentrated solution of burnt sugar, or caramel. Formerly it was merely used by the manufacturers of cordials for imparting to these products a brown color. But since imitations of rum and cognac are being made in extraordinarily large quantities, this "color" serves as an important factor in coloring these alcoholic beverages, and also when an erroneous taste desires the beer to be of a dark hue, this couleur is applied to gratify this mistaken preference. Vinegar too is frequently colored with this ingredient in order to make it resemble the French article or that made of beer. After the application for these various purposes it will be obvious whence the terms *beer-couleur*, *rum-couleur*, *whiskey-couleur*, etc., originate.

The fabrication of couleur from sugar has reached in modern times such an important place in commerce that it forms quite an item in the annals of industrial statistics.

As has already been stated sugar-couleur is divided into two different kinds, viz., those for spirituous liquors (rum-couleur) and beer-couleur. The former is used for the coloring of alcoholic liquors (rum, arrac, whiskey, etc.), the latter for coloring beer, ale, wine,

vinegar, sauces, and even serves as a coloring matter for coffee-essences. Both these coloring substances are at present prepared from the less expensive grape-sugar, and for this reason the "sugar-couleur" is of late rated at a much lower quotation than formerly, notwithstanding the fact that the quality of the product remains unchanged.

The process of manufacturing couleur, although very simple, requires accuracy, experience, and talent, so that but few establishments can furnish a thoroughly approved article.

This coloring matter is generally produced by the heating of starch-sugar in a kettle until it forms a dark-brown mass. After sufficiently cooling off, water is added in order to dissolve the substance to a dense, dark-brown liquid.* This is what is termed *couleur*.

The sugar melts while being heated, the melted syrup colors gradually more and more brown while puffing up and squirting. For this reason the kettle should be very roomy compared to its contents, and frequent stirring is also required. This operation ensues under the development of dense, whitish vapors of an empyreumatic smell. At first the fire may be allowed to burn in a lively manner, but toward the end of the process it must be modified as the melted mass might otherwise become carbonized. The time when the fire must be diminished is known to the expert by the color of the substance. It must, when taken upon a wooden spatula congelate to a dark-brown lustrous mass, and flow off from the stirrer like tar (thread-like). A wire

* Glucose is not so well adapted for this purpose as starch-sugar, on account of its larger contents of dextrine.

dipped into the kettle must become thickly covered, and form blisters. The smell and color, too, are guides to the expert.

According to the chemist Krötke, of Berlin, rum-couleur is manufactured in the following manner:—

The sugar syrup, almost entirely free from dextrine and condensed to 36° B. (weighed hot) and filtered, is while yet hot directly applied for making the couleur. In this way much is saved in fuel and labor. But if circumstances should not permit of this method, then the solid sugar is first broken up into pieces weighing about 5 kilogrammes (11 lbs.) and thus used for burning. For operating on a larger scale from 100 kilogrammes (220 lbs.) to 200 kilogrammes (440 lbs.) are usually applied at once. The boiler used for this purpose, made of strong wrought iron, is to be 1 metre (3.28 feet) high, and its upper diameter measuring 1.5 metres (4.92 feet). The bottom of the same is to be somewhat stouter than the sides, and should be spherical. To the kettle an iron stirring-apparatus is affixed, which must be kept in motion during the time the fire is kept up. This apparatus cuts accurately as far down as the bottom, so that no part of the sugar can burn to ashes. During the operation of burning the sugar, a penetrating disagreeable odor is developed; and for this reason such kettles are provided with a wooden lid and a chimney for carrying off these vapors. From the forepart of the kettle, the lid can be removed, while the other part with the ventilator chimney is fixed and permanent.

The burning of the rum- or alcohol-couleur is performed thus: From 100 to 200 kilogrammes (220 to 440 lbs.) of crushed starch-sugar, or rather hot sugar syrup, are placed in the kettle, and the fire is started

thereunder. As soon as the sugar is melted, and the syrup becomes liquid, the stirring operation commences. Usually one laborer is sufficient for this manipulation and is able to make from 500 to 600 kilogrammes (1100 to 1320 lbs.) of couleur in a day.

As soon as the melted or liquefied sugar begins to boil, 3 kilogrammes (6.6 lbs.) of crystallized soda are added for every 100 kilogrammes (220 lbs.) of sugar. The soda is to be in pieces of the size of a walnut, and to be added gradually. A handful of soda is thrown into the boiling sugar; this will cause the mass to rise under great ebullition and it must first be made to descend again, by stirring, before more soda is added. After the soda has all been disposed of in this manner, the burning is continued over a good fire. The liquid becomes more and more brown. As soon as a burning smell is observed, the lid is to be raised somewhat. The expert workman knows at once by the color of the substance, when the heating and the burning operations have to be interrupted. If the test has proved that the sugar is sufficiently burnt, then hot water is added. To every 100 kilogrammes (220 lbs.) of sugar, 50 litres (13.20 gals.) of water may be used. This must be poured in quickly, while keeping up a lively stirring. Thereupon the couleur is weighed in its hot state by an hydrometer. If the couleur shows a consistency of 35° B., it will be ready for sale; if it shows more degrees, then more water should be added; but should the article indicate but 34° or less, then it must be left to condense for several minutes longer.

The fire is now removed from under the kettle, the couleur drawn off and placed in the cooling vat. The latter is of pine-wood, and 1 metre (3.28 feet) high and

of 2 metres (6.56 feet) diameter. Upon the vat a basket of willow, 1 metre wide and 0.25 metre (9.84 inches) high, is placed, over which a large cloth of cotton of a thin texture is placed, and through this filter the couleur is poured, in order to strain off the cinders which may have formed during the operation.

The finished contents of each kettle should be tested, as to its reaction on alcohol of 82 per cent. To this end a test-tube is filled to one-half of its capacity with such 82° alcohol, pouring one drop of the finished couleur therein and shaking the same well. If the alcohol remains clear, the couleur may be stored away as 80 per cent., but in case the alcohol turns even in the least turbid or dull, then the couleur is stored away in the reservoir for that of lower percentage.

The process of manufacture of beer-couleur (also called wine-couleur) is given by Krötke, the technical chemist, as follows:—

The operation is very simple, so that every wine grower or brewer may prepare his own supply, by getting the requisite raw materials. In order to obtain practice, a commencement should be made with small quantities. For the first trial 5 kilogrammes (11 lbs.) suffice. These 5 kilogrammes of starch-sugar are put into a kettle and melted over a brisk fire. As soon as the sugar melts, it begins to bubble and to rise; when it will be necessary to stir with a wooden paddle, so that the mass does not boil over. If this is not sufficient, a little butter of the size of a pea is added, and if this does not have the desired effect, then the fire must be diminished. The sugar is now left to boil until it begins to burn. This is perceived by a penetrating smell, which causes pain to the eyes.

At this juncture 100 grammes (3.5 ozs. avoir.) of coarse carbonate of ammonia are added, and continuing the boiling while constantly stirring. Thereupon the boiling is kept up over a gentle fire, until the sugar becomes almost stiff, and it is difficult to stir the same. Then the testing begins. A small stick of wood, of the size of a penholder, is placed in the boiling mass. The substance which adheres to this stick is quickly placed in a glass of cold water, and thus suddenly cooled off. If the cooled-off couleur is entirely brittle, and can be easily bruised between the fingers, it is finished. Should the sample still appear very hard, and its taste be sweet, the burning process must be continued until this sweetish taste disappears and the sample proves to be brittle. The manipulation on a larger scale is essentially the same.

The couleur after cooling off is filled into bottles and barrels.

If the sugar is of a good quality and the operation properly conducted, a fine coloring substance of intensive quality is obtained, which will color all light malt liquors brown, and which imparts to white wines a fiery golden-yellow hue, and red wines will obtain a darker shade by its application.

With this wine- or beer-couleur, spirits of a lighter percentage may be also colored. Couleur prepared with soda is, however, not suitable for coloring vinegars, because the humid substance, which is formed by the action of the soda upon the sugar, is separated by the acetic acid forming a combination with the soda.

The following receipt, furnished by Professor Otto, is the basis of directions for the manufacture of *sugar-couleur:* 140 kilogrammes (308 lbs.) of yellowish starch-sugar are melted in an iron kettle. After complete

liquefying, 4 kilogrammes (8.8 lbs.) crystallized soda are added, and the melting is continued until the above described phenomena ensue, after which the boiling is to be continued over a slow fire, for five minutes longer. After sufficiently cooling off, from 71 to 73 litres (18,744 galls. to 19,272 galls.) of water are added, during which the stirring is not to be interrupted. The entire operation requires but two hours, and an excellent article is the result.

PART III.

THE MANUFACTURE OF DEXTRINE.

SECTION I.

THE CHEMISTRY OF DEXTRINE.

History, Literature, and Terminology.—In the year 1810, *Bouillon Lagrange* made the important discovery that starch, when slightly roasted, acquires the property of being soluble, in cold water, into a mucilaginous (gum-like) liquid. This discovery was accidentally made at the time of the continental blockade, when the price of gum-arabic was unusually high. This circumstance gave inducement for applying the torrified or roasted starch as a surrogate for the Arabian and Senegal gums in finishing calicoes.

Considering the circumstance, that roasted starch possesses such properties, which make it sometimes a perfect substitute in lieu of the always more expensive foreign gums, the discovery of Bouillon Lagrange appears to be of great importance, and in case of emergency the oriental product may be entirely dispensed with.

At first the starch was roasted in iron kettles or drums, which, especially in the former case, caused many inconveniences. In order to avoid these, *Dingler*, in 1820, proposed to roast the starch in whole pieces

on iron plates, in a heated bake-oven. With the view of retaining the product still more gum-like, *Kurrer* performed the roasting in an iron vessel over a coal fire, by constantly stirring the starch mass, so that the starch ran together into a brownish substance, whose watery solution, when carefully evaporated to dryness, assumed a dark brown lustrous appearance, similar to rosin. Since 1829, *Guibourt*, a French chemist, has made many experiments and investigations respecting the production of dextrine. *Doeberreiner* found that the solubility of the roasted starch is dependent on the temperature maintained during the process of roasting, while *Payen*, already as early as 1834, proved, that the most suitable temperature for the roasting, in order to produce the dextrine, is from 200° to 210° C. (392° to 410° F.), and that dextrine obtained at these degrees of heat will dissolve most perfectly.

An explanation of the transformation of starch by means of roasting was easily rendered during the years immediately preceding 1829. As starch, according to the investigations made by *Loewenhoek* (1816), and somewhat later by *Guerin Vary*, consisted of granules whose hulls and contents chemically vary; and *Raspail* believed he had found (1825) that the hulls are indissoluble in water, while their contents are soluble therein, and are identical with gum. At that time it was accepted, that by the roasting of starch, the hulls are emptied of their granules, and their contents become soluble in water, and after evaporating such a solution remains as a precipitate. But *Lassaigne* had already, in 1820, drawn attention to the fact, that starch did not contain any gum, since by heating it with nitric acid, no pyro-mucic acid, as in the case of natural gum, was produced, but oxalic

acid. *Fritzsche*, in 1841, proved most decidedly that no substance soluble in water is contained in starch, while *Guibourt* already, in 1829, perceived the difference in the structure of the starch granules depending on the various states of aggregation of one and the same substance. The ideas hitherto entertained as to the origin of dextrine from starch during the roasting process, became thus untenable, more especially when soon thereafter such authorities as *Payen*, *Fritzsche*, *Persoz*, *Schleiden von Mohl* and *Nægeli* explained that pure starch was of an identical composition, and that only the inner strata of the starch granules contain a larger quantity of water, and are of a lesser density, than the outer layers. By this discovery it was at the same time ascertained that dextrine is not a preparation separated from the starch by roasting, but is first formed by the roasting. This view is even to this day the only correct one.

The literature pertaining to dextrine and its manufacture tends to the year 1811, but extensive treatises on this subject have never yet been published in book form, while the magazine literature respecting this article is indeed fertile enough.

The term *dextrine* originated with *Biot* and *Persoz* who, in 1833, proved that it essentially differs from Senegal or Arabian gum, and whereas the solution of dextrine does not turn off the surface of the polarized rays to the left, but towards the right side ("dexter"), and this it does more powerfully than any known organic solution, and hence they gave to this product the name dextrine, a name which *Berzelius* reproved and criticized for scientific reasons, because hundreds of substances could perhaps be found possessing this same peculiarity. Dextrine is also called *dextrine-*

gum, fruit-gum, roasted starch, starch-gum, steamed-gum, Amidon-grillé, Leiocome, Leiogomme, Gomme d'Alsace, Gommline, etc.

Substance and Nature.

Biot and *Persoz* believed at first that dextrine was not at all a product of the action of sulphuric acid on starch, but that it pre-existed in the latter as dextrine, and merely issued from the broken hulls by the bursting of the starch-granules during the process of boiling in a moderate quantity of pure acidulated water. In opposition to this doctrine, *Payen* and *Persoz*, in 1833, considered dextrine as being not a simple chemical body, but a mixture of three different substances, *i. e.*, of starch-sugar, being soluble in alcohol, and two other substances indissoluble in alcohol, which two latter comprise the dextrine of *Biot* and *Persoz*. They based their opinion on the fact, that that part of dextrine not soluble in alcohol, after drying, when mixed with cold water, only partially dissolves therein, while one part remains an indissoluble residuum. Meanwhile dextrine or starch-gum is nevertheless to be considered as a specific intimate ingredient of plants, and the above-mentioned part which is indissoluble in water is to be considered as an impurity thereof, perhaps as particles of starch, that is as starch particles, which have not yet passed over into dextrine, or perhaps as a peculiar intermediate link between starch and dextrine.

Dextrine is always composed of the same elementary bodies, no matter in what manner it may have been produced or formed, and despite the various physical modifications in which it occurs, whether it has been

produced by sulphuric acid, diastase, potash, etc. It always corresponds to the formula:—

$C_{12}H_{10}O_{10}$ (or according to the new mode $C_6H_{10}O_5$) and hence is of the same composition as starch.

Origin and Formation.

Dextrine appears in nature not generally diffused throughout the vegetable kingdom, but it occurs, however, mostly in small quantities in many plants. It seems to act an important part in the development of plants, especially in those parts of plants in which a new formation of the cells takes place. For this reason many physiologists, for instance *Schleiden*, deem dextrine to be really that part of the plant by which new plants are formed.

Grain always contains certain quantities (4 to 7 per cent.) of dextrine.

According to analytical tests—

Air-dried wheat contains		4.5	per cent.	dextrine.
Wheat bran	"	5.52	"	"
Rye bran	"	7.79	"	"
Barley	"	6.55	"	"
Malt	"	8.23	"	"

Dextrine is also frequently found in larger quantities as the product of transformation of grain-starch in bread, in beer, and in many other articles of food made of grain.

In the animal kingdom dextrine is found in the blood, muscles, spleen and liver, but more especially of those animals which are fed with grain.

When dry starch is heated to a temperature of from 212° to 275° C. (413.6° to 527° F.) and in this temperature kept for some time, it attains gradually the

color of yellow, brownish-yellow, or yellowish-brown, and thus becomes roasted gum, or dextrine.

By treating starch in diluted acids or by the action of the diastase (malt extract), dextrine is likewise obtained.

The solution of the diastase is capable of transforming starch—especially at a temperature of from 70° to 75° C. (158° to 167° F.), into dextrine and starch-sugar, *i. e.*, it possesses at this temperature the highest degree of potency.

In general, however, the action of the diastase on starch is limited, that is in so far as it shows its action at all, only between —10 and +80° C. (14° and 176° F.). That the formation of glucose is always preceded by that of dextrine, has been already amply set forth, and nothing remains to be said in this connection, but that neither of these products originates exclusively, but that besides dextrine, sugar is always formed and the reverse.

Chemical Properties.

Dextrine is an hydrate of carbon of the same elementary composition as starch, *i. e.*, $C_{12}H_{10}O_{12}$; or according to the new mode $C_6H_{10}O_5$; being formed by the heating of the starch, but not, as was formerly erroneously believed, separated therefrom. Payen had furnished the proof as early as 1836, that dextrine in its various modifications is of the same composition, whether it be formed by the wet process, by the action of acids, diastase, or by alkalies, etc., or by the mere heating (roasting) of the starch. Professor Otto of Brunswick, on the other hand, is of opinion, that the "roasted starch" is not identical with that article,

which has been produced by the aid of the designated chemical ingredients. The chemically pure dextrine furnishes a perfectly white, amorphous, tasteless and odorless powder of 1.52 specific gravity. It dissolves in cold water completely, and forms a glutinous, mucilaginous neutral solution, which is colored dark red by iodine. This coloring disappears by heating it to 40° C. (104° F.), but reappears after cooling off. The dextrine of commerce when dissolved leaves twelve or more per cent. of unchanged or burnt starch as a residuum.

By applying diluted acids—whether sulphuric acid, muriatic acid, or acetic acid is used—dextrine becomes partly transformed into grape-sugar (dextrose) when being heated, and while absorbing water. This is likewise the case with the action of diastase or malt (at a temperature of from 60° to 75° C.=140° to 167° F.), however only to a certain limit. In absolute alcohol and in ether, dextrine is indissoluble. In an alkaline copper solution (Fehling's solution), dextrine when being heated does not separate at once protoxide of copper, but by continued boiling of the mixture it precipitates in small portions. With bromide, and oxide of silver, dextrine may be changed into dextrine-acid. Many metal-oxides, while being insoluble in water, are soluble in a solution of dextrine, especially when potash is present.

It has frequently of late been a matter of inquiry, whether dextrine is fermentable. Recent investigations in this direction have clearly proven that dextrine by itself is not fermentable. A pure solution of dextrine, mixed with beer yeast, does for this reason not ferment.

The influence of an increased temperature on dex-

trine has been thoroughly investigated, and the results attained in this direction are as follows: 1, that dextrine exposed to a higher temperature in an indifferent gaseous substance (*i. e.*, in an inert gas, loaded with moisture) transforms into sugar; 2, that thereby as much more glucose is formed, the more acetous the starch is that is applied.

Musculus has made within the decade now passed some highly interesting experiments respecting soluble starch and globulous dextrine.

Globulous dextrine is the designation of a substance which is indissoluble in cold water, and is obtained by the dissolving of starch in boiling acid water, and by neutralizing the acid, and evaporating it into syrup. It was deposited therefrom in abundant quantities of granules, which are not soluble in cold water, but in such of a temperature of 50° C. (122° F.), and hence can be easily freed of the adhering dextrine and glucose by washing. After a small amount of the granules, of which it consists, has been extracted by alcohol, a pure soluble starch is obtained, consisting of granules of the shape of the original starch used.

SECTION II.

THE TECHNOLOGY OF DEXTRINE.

The Manufacture of Dextrine.

The manufacture of dextrine results from starch, by the heating of the same with acids or with diastase (malt extract). In industry the term dextrine only signifies starch dextrine, *i. e.*, such preparations as have been obtained by the artificial transformation of starch, containing usually besides dextrine also unchanged starch, soluble starch, glucose, and water in considerable quantities. In the manufacture of dextrine the following observations are of the greatest moment:—

1. The roasting of starch at a suitable temperature.
2. The heating of starch with diluted acids for a short time, or
3. The treatment of starch with a solution of diastase in a temperature ranging between 60° and 70° C. (140° and 158° F.) for a brief period.

These are the conditions for obtaining the largest possible quantity of dextrine and the least possible amount of starch-sugar. For the industrial production of dextrine, the principal point in view is, therefore, that on the one hand the starch is transformed as completely as possible into dextrine, and on the other hand, that the sugar-formation which will more or less ensue is possibly prevented. The purity and

the value of the product depend above all on the observation of these two points. Of course the manufacturer must, as is self-evident, pay attention that the dextrine is produced as profitably as possible; hence it is of less importance to furnish a chemically pure article, since this is but seldom demanded for practical purposes. The obtaining of a well pasting and thickening article is what is most desired.

For the manufacture of dextrine such starch is applied as is most easily attainable at the place of its manufacture.

The production of dextrine from starch is performed in three different ways, to wit:—

1. By mere roasting.
2. By the action of acids.
3. By the action of diastase.

1. The Manufacture of Dextrine by the Roasting of Starch.

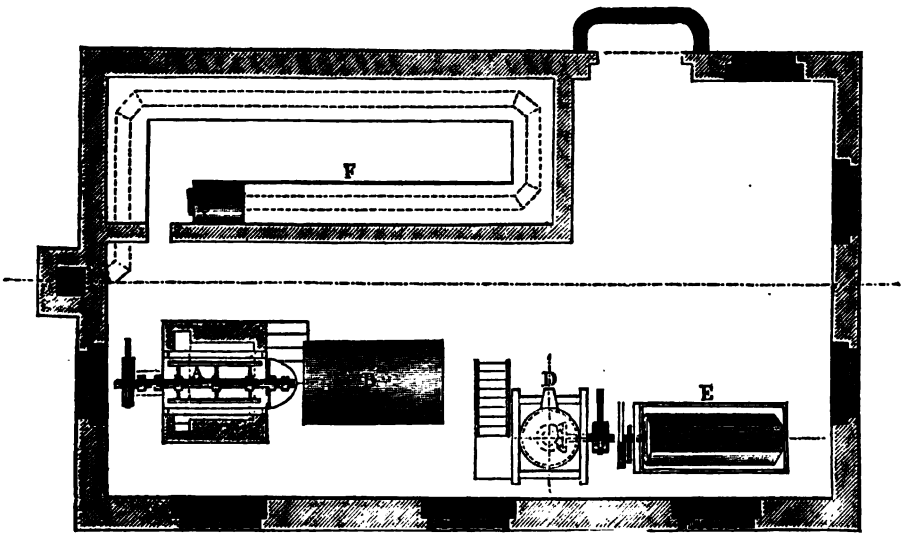
When dry starch is heated at a temperature of 212° to 250° C. (413°.6 to 482° F.), and is for some time kept in this temperature, it will, according to the same, be transformed into one of the following shades of color: yellow, brownish-yellow, or yellowish-brown, and is thus changed into roast-gum or dextrine. The process of manufacturing roast-gum is very simple. It is only requisite to manage the operation of heating in the most suitable manner; in fact, so that the transformation of the starch ensues very evenly, and as completely as is possible at the designated temperature. To this end various propositions have been made.

The best and most secure way of regulating the temperature is by means of an oil-bath. A flat kettle,

with a slightly convex bottom, is suspended in a second somewhat larger kettle, in which oil is contained, so that the first kettle is surrounded by the oil. A thermometer, inserted in the oil, indicates the temperature. A stirring-apparatus of metal, touching the bottom of the inner kettle, and by which the starch placed therein can be turned, gradually causes the starch-granules to come in contact with the sides of the kettle, and thus obtain the required temperature for the transformation of the starch into roast-gum.

An excellent apparatus, constructed on the principle just described, is delineated by Figs. 46, 47, and 48.

Fig. 46.

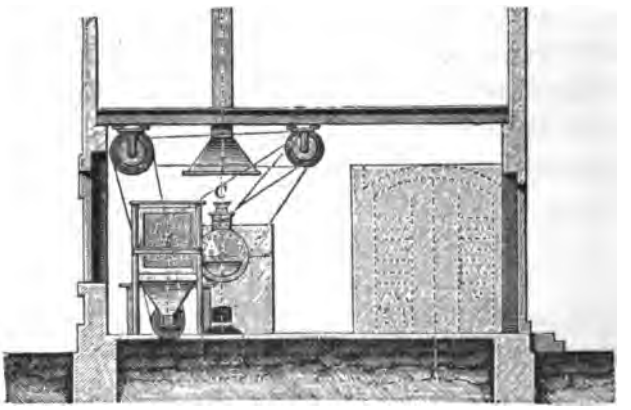


Dextrine roasting apparatus. (Ground view.)

This dextrine roasting apparatus consists of a double cylinder of wrought-iron plates, which is supplied with an hermetical *closure*, easily accessible on both sides, and a well-constructed stirring appliance.

On the upper part of the cylinder an oval-formed hopper, *C*, is placed, by means of which the apparatus is from time to time supplied with starch. By the aid of this apparatus, wheat-, rice-, or potato-starch can be

Fig. 47.



Dextrine roasting apparatus. (Lateral section.)

transformed into dextrine, as long as only a roast-gum in powder form is to be produced; but not in the shape of transparent pieces resembling the natural gum. But the starch must of course previously be made entirely free from its 17 per cent. of water. This is done by drying in the drying-room, *F*, at 80° C. (176° F.).

The loss of weight ensuing afterwards in the roasting apparatus will be very small. It may be generally accepted that 100 kilogrammes (220 lbs.) of air-dry starch—in the form as it is obtained from the starch manufactories—furnishes on an average 80 kilogrammes (176 lbs.) finished roast-gum of a good quality.

By means of this apparatus the following articles can be produced from starch:—

Gommeline (white dextrine).

Dextrine (light-yellow dextrine).

Gommes factice (dark-yellow dextrine).

Leiogomme (burnt or calcined starch), and neutral white yellowish dextrine.

From wheat-starch:—

Adruganline (white dextrine).

Gomme cériale (yellowish dextrine).

Amidon-grillé (calcined wheat-starch), etc. etc.

By means of this apparatus the value of the starch to be worked up into dextrine is increased 20 per cent. over and above that produced by any other mechanism.

The impelling power required for this apparatus is about one-eighth horse-power, and the stirring machine makes eight revolutions per minute.

This apparatus is applied as follows:—

The double casing of the machinery *A* having been filled to the height of the gauge-cock with well refined rape-seed oil, a fire having been kindled under the cylinder, the stirrer is put in motion, and the apparatus is filled with anhydrous starch (250 kilogrammes = 550 lbs.), by means of the hopper *c*.

The oil gradually expanding by the great heat that ensues rises noticeably, so that in a very short time the entire inner cylinder will be surrounded by it. Gradually the oil enters the oval barrel *A* (Fig. 48), which, for the sake of security, is supplied with a waste pipe.

Inasmuch as the rape-seed oil is a poor conductor of heat, and hence retains the once acquired temperature for a long time, a moderate fire suffices for the creation of the diverse degrees of heat requisite for producing the various kinds of roast-gum. The roast-gum is fin-

ished as soon as a decided smell becomes noticeable near the hopper, and the emptying of the apparatus must be

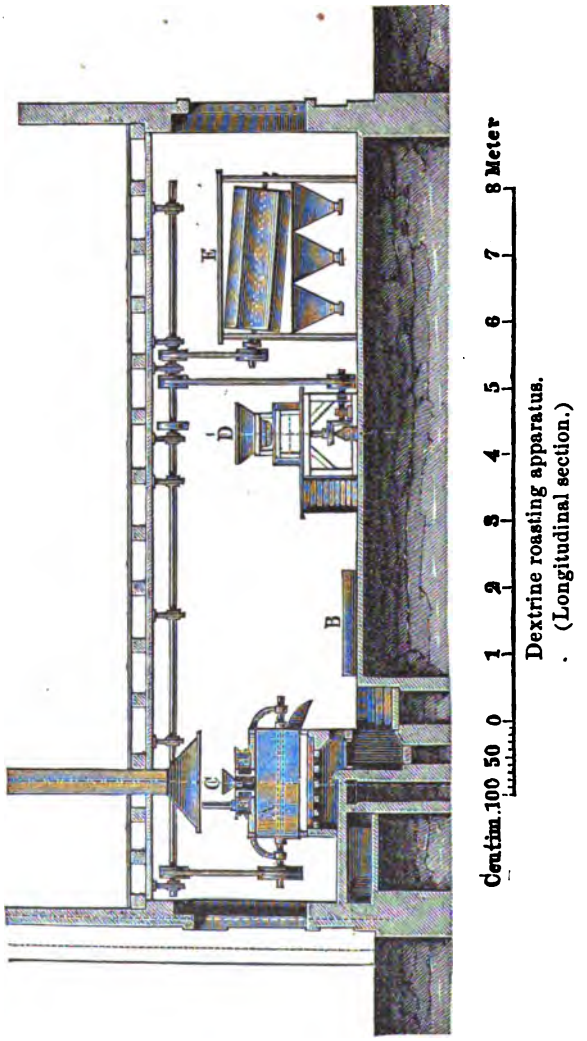


Fig. 48.

Dextrine roasting apparatus.
(Longitudinal section.)

at once attended to, by the opening of one of the front closures. The roast-gum having mostly formed in pieces is then placed in the metal dish *B*, which is

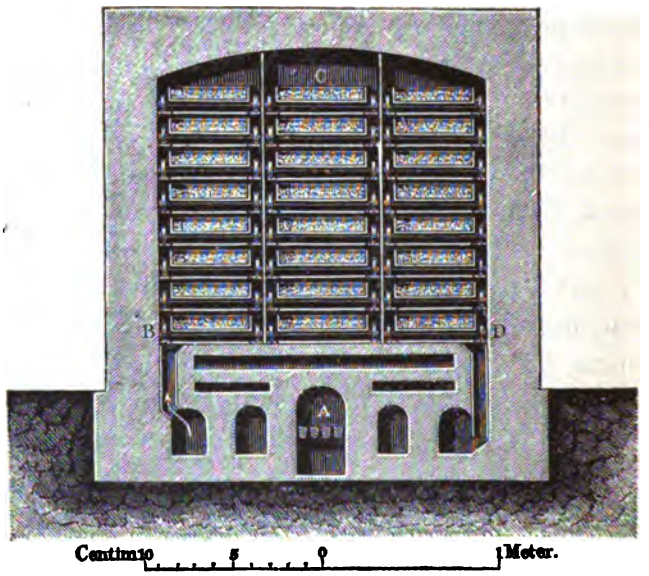
about 2.5 metres (8.2 feet) long, and 1.2 metres (3.94 feet) wide, the larger pieces being crushed and sifted preparatory to pulverizing the same in the crushing mill *D*. But inasmuch as such a bruising mill does not turn out the roast-gum quite evenly, it is also placed in a sieve-drum, or in the gauge-cylinder *E*, and is then ready for packing.

The oil in the casing can be used for several months, and needs only to be replenished occasionally when it becomes thickened by decomposition. For the roasting of starch large cylinders of wrought iron are also sometimes used, similar to those which are in use for roasting coffee. Instead of the common roasting cylinders, which have to be periodically filled and emptied, a machine consisting of a cylindrical roasting apparatus which can be constantly kept in motion is often applied. These cylinders are usually made of wrought iron of 3.2 metres (10.5 feet length, and 0.32 metre (1.05 feet) diameter. They are placed in an inclined position over a fire-place, in the higher end of which the starch is put in, at the same rate as from the lower part thereof the roast-gum is emptied. For producing the darker product the first article is passed again through cylinders at an increased heat. Generally several cylinders are placed over the same fire, and their turning is managed by cog-wheels. In the large establishment of *Proudfoot & Co.*, in Manchester, England, five of such iron cylinders of 3 metres (9.84 feet) length, and 0.3 metre (0.98 foot) diameter are placed retort-like alongside and above each other in a common furnace, and as has already been stated, in a somewhat inclined position. In this factory 4000 kilogrammes (8800 lbs.) of dextrine are produced daily.

A very simple contrivance, although less suitable

for the purpose of producing dextrine, is the apparatus constructed by *Payen*. It consists of a furnace with a hot blast (Fig. 49), which permits of the production of an even and sufficiently high temperature.

Fig. 49.



Furnace for the production of starch-gum according to Payen's construction.

The upper space of the immured furnace serves for the reception of the dry starch, which is divided into layers of from 3 to 4 centimetres (1.18 to 1.57 inches) in height in light boxes made of brass plate. The process of roasting is performed by heated air. Of course a thermometer must indicate the temperature of the chamber. The heated air takes up the heat which is imparted to the walled-in apparatus and circulates in the channels as represented in the sketch (Fig. 49), enters into the furnace by *B*, spreads out therein, heating the walls and the starch, and returns thereupon by

D into the channels to become again heated and to traverse over the same space. The starch thereby again gradually turns yellowish-brown, and is then in a great measure soluble in water, and is transformed into roast-gum. Of course the heating-chamber is to be supplied with iron frames for the insertion of a corresponding number of boxes.

Inasmuch as the starch contains a considerable amount of water, the process of roasting must needs be preceded by a corresponding drying of the starch. Thus at the beginning preparations for the withdrawing of the moist air must be made. For this purpose an aperture is made in the very accurately fitting iron door, which is afterwards closed. Prof. Otto, of Brunswick, justly remarks, that it would be hardly possible in such a roasting chamber to raise the temperature evenly to the required height, nor can the starch while lying on the iron boxes obtain an even roasting, inasmuch as it is not turned over.

In conclusion may yet be mentioned *Pochin* and *Wooley's* patented method of manufacturing dextrine. The completely dried (but not roasted) wheat or potato-starch is mixed with one-fourth to one-eighth weight part of butter-milk or sour milk, sifted through a fine wire sieve of 150 meshes per square decimetre (decimetre = 3.937 inches), and after drying again, is roasted at a gentle heat until it appears yellowish or brownish. According to the quantity of the butter-milk applied, the dextrine will take a more or less light-yellow color, and thus any desired shade of color can be attained.

2. The Manufacture of Dextrine by the application of Acids.

If dry starch is moistened with water, to which a small quantity of a non-volatile or at least not very volatile acid has been added, and thereupon, after being previously dried, is exposed to a temperature of from 100° to 125° C. (212° to 257° F.), it will transform into dextrine. Dextrine obtained in this manner, is generally of a lighter color than the leiogomme, which is produced by simply roasting the starch.

The production of dextrine by means of acids is therefore a very simple affair, and is even easier to accomplish than the manufacture of roast-gum, since for this operation a less high temperature is required. But by this method, great care must be observed that the action of the acids is arrested as soon as the transformation of the starch into dextrine has been completed, which can be proven by the iodine test. As long as the mass yet contains unchanged starch, it will be colored blue by the application of iodine. But whenever the reaction of iodine ceases, this will be a sign of the complete transformation of the starch. The action of the acid must at once be interrupted so as to prevent a considerable part of the formed dextrine passing over into sugar.

In order to prevent the formation of sugar in the process of manufacturing dextrine, or at least to limit the same, it would be best never to heat the starch with acid and so much water, that the forming dextrine can become dissolved. For not alone in this case does the evaporation of the liquid mass require large quantities of fuel, and thereby occasion considerable expense, there would also during the evaporation of the

dextrine solution be a considerable part of the dextrine transformed into grape-sugar. This would be caused by the prolonged action of the acid still contained in the dextrine solution. In practical operation the starch, therefore, is mixed with the necessary quantity of dilute acid—based on experience—in a moist powder, and this powder is exposed to a suitable temperature (100° to 120° C. = 212° to 248° F.) until a complete transformation of the starch ensues. Among acids, muriatic and nitric are the ingredients which are chiefly applied for the making of dextrine. The acids must above all be free from gaseous chloride, since this otherwise passes over into the formed dextrine. This would cause the colors which are prepared with such dextrine—for paper and cloth printing—to lose their intensity, that is to say, they would be bleached. Sulphuric acid does not often find application in the manufacture of dextrine, but is still sometimes used for preparing liquid dextrine. Dextrine obtained by its application has the peculiarity of easily becoming sticky, and even does not entirely lose the same by drying as the sulphuric acid is but slightly volatile. Such dextrine is also generally of a darker color. But, on the other hand, for the production of liquid dextrine oxalic acid and lactic acid are frequently used, and their excess must after completion of the transformation of the starch into dextrine be separated or neutralized by means of carbonate of lime. Thus oxalate of lime is formed, which does not cause the formation of sugar, during the evaporation of the dextrine solution.

Fr. Anthon describes a new method of manufacturing dextrine. Hitherto pure starch only has been applied for the production of dextrine; while allowing the loss of that starch during the process of

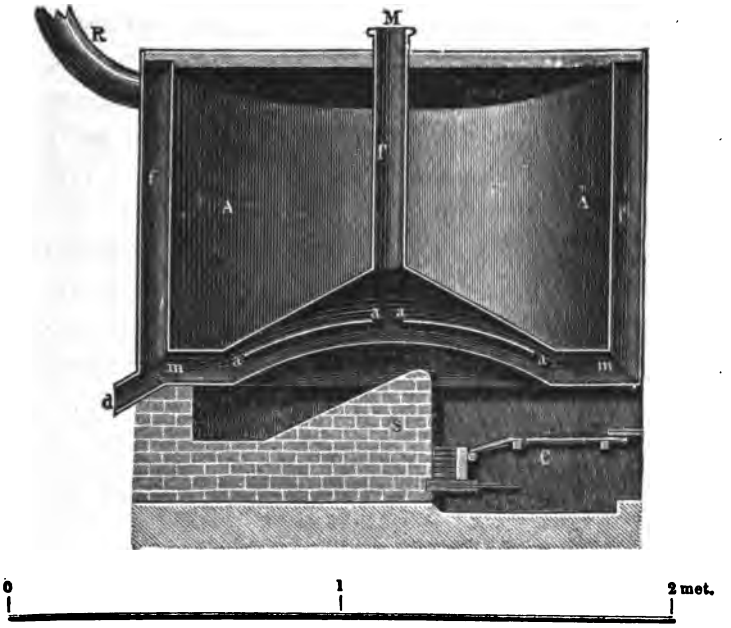
making potato-starch which is contained in the starch fibres. In order to avoid this loss the entire substance of the potato can be applied. The potato is to this end previously freed of its soluble ingredients by extraction with acidulated or alkaline water, and thereupon dried and milled fine.

Such starch is as usual soured with hydrofluoric silicic acid in the ratio of from five to ten per mille of the weight of the starch. This acidulated starch is then spread in the drying-room upon linen hurdles, and dried in a temperature of from 38° to 44° C. (100.4° to 111.2° F.) so long until it no longer decreases in weight. The temperature is then raised from 70° to 75° C. (158° to 167° F.), and it is also left in this temperature until its state of dryness corresponds therewith. Thereupon the temperature is increased to 90° C. (194° F.), and it is thus kept for half an hour, and, finally, the perfectly dried starch is put while yet hot into moulds of tin plate and kept therein for a period of from one to two hours in a temperature of 100° to 125° C. (212° to 257° F.), until the dextrine formation is finished, that is, when a sample taken therefrom, after cooling off and being moistened with cold water, assumes a nice, glassy, transparent, globular formation.

The apparatus required for this purpose, designated as the dextrine cellular apparatus (Fig. 50), consists of a cubic-shaped metal boiler (kettle) *f m a a m f*, which serves for the water-bath (salt lye, or eventually also as oil-bath), and which can be heated according to requirement to from 90° to 125° C. (194° to 255° F.). Inside of this apparatus are inserted flat tin cells *A A*, of a corresponding height and width, but they must not exceed the diameter of 25 millimetres (0.984 inch) in thickness. They are designed to expose the acidy

and dried starch to a temperature of from 100° to 125° C. (212° to 257° F.) until the dextrine formation is finished. The respective cells are placed in the kettle surrounded by the bath at a suitable distance from

Fig. 50.



Dextrine cellular apparatus of recent construction.

each other, and after the process is finished, taken out to be emptied and refilled, or they may be fastened in the kettle, as is the case in our sketch. In this event they are supplied with an inclined bottom.

The fireplace for heating this apparatus is to be so constructed that the heat can be turned off at once, in order by application of the oil-bath to avoid an overheating. The outer walls of the apparatus are to be lined with flannel and wood. The intermediate bottom *a a a a* is to effect a rapid circulation of the liquid, lye,

or oil. The pipe *R* serves for cooling off at will the cells with their contents. Through this pipe a cold liquid can be conducted into the kettle at any time, but of course only after draining off the hot lye or oil by means of two stopcocks which are placed on the side of the apparatus.

As is obvious, the apparatus above is supplied with a well-fitting cover, so that no lye or oil can boil over.

The following is a receipt for producing dextrine by means of oxalic acid: 500 weight parts of potato-starch,* 1500 parts water, and 8 parts of oxalic acid are heated in a water-bath, until the tincture of iodine no longer colors the liquid blue. After cooling off, the solution is neutralized with chalk, permitting it to rest for several days, then filtered and evaporated to the consistency of dough. This mass is finally slowly and perfectly dried.

3. The Manufacture of Dextrine by means of Diastase.

Ere yet the simple process of manufacturing dextrine, now in vogue, was known, dextrine already existed as a commercial commodity, but it had quite a different appearance, and was produced in a different manner. A solution of malt, starch, and the requisite quantity of water was heated at a high mashing temperature, 75° C. (167° F.), and finally brought to a boil, and after filtering, it was evaporated to the consistency of a thick syrup, and this mass was dried out. The substance thus obtained was similar to gum-arabic.

* Corn-starch will answer the same purpose, providing the quantity of the acid is somewhat increased.

It was a mixture of starch-gum and sugar, but it passed in commerce as dextrine or starch-gum.

The making of dextrine by means of diastase is no longer in use, but nevertheless we will briefly describe this method.

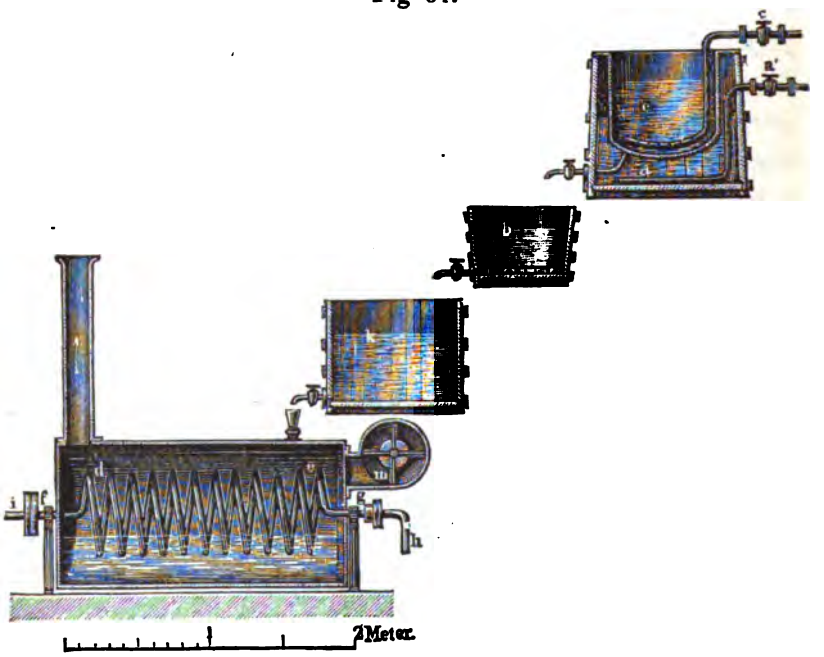
For the production of dextrine by the action of diastase on starch, an extract of "germinated barley" (malt extract) or finely ground malt is applied, the diastase thereof being of greatest effect at a temperature of from 65° to 75° C. (149° to 167° F.). At a lower temperature the formation of dextrine ensues but slowly, and in an increased heat it ceases entirely. As soon as the transformation of the starch into dextrine is effected, the mass composed of dextrine malt and water, is immediately boiled, whereby a further transformation of dextrine into sugar need no longer be feared. Nevertheless, the dextrine obtained in this way will never be entirely free from sugar. However, the sugar contained in dextrine is for many purposes even desirable, and for this purpose such a product is prepared by some French manufacturers intentionally. It is introduced into the traffic as *dextrine-sucrée* (dextrine-sugar).

This method of manipulation is therefore much more simple than those heretofore described, but its general introduction is hindered by great obstacles. These are: 1, the large amount of water contained in such dextrine (dextrine syrup) makes the transportation difficult; 2, by the application of malt, as has been heretofore elucidated, it is unavoidable that a part of the starch be transformed into sugar, and by these admixtures the dextrine syrup loses a great amount of its durability, and aided by the non-separated parts of the gluten of the malt becomes very easily fermentable.

Payen has constructed an apparatus for the production of dextrine with diastase (Fig. 51).

For the manufacture of dextrine by this method, the copper boiler, *c*, is suspended in a wooden vat, *a*, half filled with water. The vat as well as the inserted boiler is connected with steam-pipes, in which nume-

Fig 51.



Payen's apparatus for the production of dextrine with diastase.

rous openings admit the steam as it may be required. To accomplish this, the stopcocks *c'* and *a'* need only be opened. The inner boiler is filled with cold water, and in this the coarsely ground malt is placed. The steam-cock *a'* is then opened, and steam is permitted to stream in, until the water in the outside tank gradually reaches a temperature of from 60° to 70° C. (140° to 158° F.). This temperature is maintained constant by means of

slowly admitting more steam. This heat is imparted to the malt decoction, and it raises this also to 70° C. (158° F.), a temperature most suitable for the formation of dextrine. The diastase changes in the first place the starch of the malt itself, but in order to exhaust its effect more starch is added, as long as this will yet be dissolved. *Payen* and *Persoz* recommend for this purpose the mixing of from 6 to 10 weight parts of bruised malt with 400 parts of water, to increase the temperature to 70° C. (158° F.), and to add to this mixture 100 weight parts of starch. It is best to take potato-starch. The temperature is thereupon gradually raised to 75° C. (167° F.), and while stirring the mixture is kept at this temperature, until it becomes a clear and thin liquid. This usually requires a period of half an hour. After the starch is liquefied, the temperature must be quickly increased to from 95° to 100° C. (203° to 212° F.), and the mass be kept boiling for several minutes. Of the sufficient transformation of the starch into dextrine, and starch-sugar (glucose), the application of the iodine solution will convince, by taking out of the copper boiler, *c*, from one to two drops of the liquid and mixing it with a drop of an aqueous iodine solution. As long as a blue coloring ensues, the mass in the boiler still contains undecomposed starch; but if the liquid is colored a "burgundy red," this may be accepted as a proof of the complete transformation of the starch. The further action of the diastase on the formed dextrine is then to be interrupted, by opening the steam-cock, *c*, entirely; and by causing the mass to boil quickly. If the action of the diastase had not been caused to cease, a product too rich in sugar would have been the result.

As soon as the liquid has been caused to boil, and

the action of the diastase is thus destroyed, the boiling liquid is permitted to flow, by opening the cock, through the filter *b*, and from thence into the reservoir *k*. The further concentration ensues in the apparatus *d*, in whose horizontal kettle a long worm-pipe, *d e*, is affixed. The exhaust-steam of the engine enters at *i f*, the pipe itself rests in a box, *g* and *f*, and is kept in motion by a pully near *f*. The boiler is filled to about one-half of its capacity with the liquid from the reservoir *k*, into which the steam-worm is inserted. This maintains it in constant motion, and lifts by every revolution parts of the liquid to the surface, and the water is quickly turned into steam. To increase the evaporation, a blower, *m*, drives a brisk stream of air across the boiling liquid, and drives the forming vapors in the direction of the dart through the chimney into the open air.

The concentration of the liquid is carried on so far, that it forms such a refractory mass when cooled off, that the hydrometer no longer sinks; hence its technical appellation, "imponderable syrup."

This dextrine is frequently applied by brewers in France. The syrup which is not colorless is nevertheless suitable for this sort of application, since the color does no harm.

Experiments for producing Dextrine from Wood.—As early as 1820, *Bracannot* tried to produce dextrine from the fibre of wood, but without any particular success. But *Vogel*, *Bertholet*, and, later, *Anthon*, accomplished this object with far better results; but all endeavors for the solution of this highly important matter, for practical purposes, have thus far resulted in but little of importance, and it will therefore be sufficient merely to explain here a series of experiments, made by Anthon, with a view to transform wood into dextrine.

Three small pasteboard-like pieces of white air-dry paper, called "stuff" by the paper manufacturers—each of these pieces weighing 1.28 grammes (19.75 grains)—were dried in a temperature of 87.°5 C. (189°.5 F.), whereby the weight of each was reduced to 1.17 grammes (18.05 grains). These were then at once saturated in diluted muriatic acid, and thus:—

a, with 120-fold diluted muriatic acid of 16° B.
b, " 90 " " " "
c, " 60 " " " "

left for a period of four hours.

After the lapse of this time the "stuff" was withdrawn from the muriatic acid, and the acid permitted to drip off, and the stuff was then reweighed. The weight of

a, was then 3.36 grammes (51.84 grains).
b, " 3.37 " (52 ").
c, " 3.36 " (51.84 ").

The "stuff" therefore had absorbed double of its original weight of muriatic acid, and was then spread on a glass plate, completely dried out to 1.75 grammes (27 grains), and heated in glass tubes over a salt bath to a temperature of 112°.5 C. (234°.5 F.) and kept in this temperature for three hours.

These three samples appeared to be of a dirty yellowish color, and each of them weighed 1.32 grammes (20.36 grains). Wet with cold water, the yellow color became much plainer, and soon appeared light brown, *a* but little, *b* more so, and *c* most.

When sprinkled over with water, none of the three samples appeared like dextrine, because it was neither mucilaginous, nor even transparent. Heated in water

to a boil, the pasteboards, resembling strips, retained their shape unaltered. Perfectly dried, they weighed

a,	1.066 grammes	(16.45 grains),
b,	1.051 "	(16.22 "),
c,	1.051 "	(16.22 "),

and hence they had imparted to the water but 9.4 per cent. of soluble matter, notwithstanding the fact that one part thereof may have been composed of clayey substances.

From this series of experiments it becomes therefore evident that muriatic acid in respectively 190, 90, and 60-fold dilution, and applied as stated at a temperature of 112° C. (233°.6 F.), acts but very imperfectly on wood fibre, so that at best but 9.4 per cent. of this fibre thereby becomes soluble.

In a similar manner a great number of other experiments of this kind have been conducted by many modern chemists, but thus far without attaining any practical result.

Manufacture of Chemically Pure Dextrine.—All the methods of producing dextrine, as hitherto described, furnish an article which for all industrial purposes is sufficiently pure and perfectly applicable, although it still contains starch not quite converted and burnt parts of the same, and also grape-sugar in more or less considerable quantities.

But in practice sometimes chemically pure dextrine is needed, which can be best obtained by the process of refining the common commercial dextrine.

If chemically pure dextrine is to be produced, the aqueous solution of commercial dextrine is first to be discolored by boneblack, and after filtering and concentrating the same by evaporation, it is mixed with absolute alcohol. The alcohol effects the separation of the

sugar from the dextrine, while the sugar remains soluble in the liquid; the dextrine being insoluble in alcohol separates in the form of a flocculent precipitate. This precipitate is filtered off, dissolved in water, again mixed with alcohol, until the ensuing precipitation no longer increases. The flaky, separated dextrine is washed over a filter with alcohol in order to eject the last traces of sugar. But in this condition the dextrine is not yet perfectly pure, and it is for this reason again dissolved in water and precipitated in alcohol, and the filtrate again washed out; and this alternately dissolving in water and precipitating with alcohol is repeated so long until a sample of the last remaining dextrine, when dissolved in water and mixed with an alkaline solution of oxide of copper and heated, no longer forms a red precipitate of peroxide of copper.

According to *Payen* this operation, namely, the alternate solution of dextrine in water and precipitation with alcohol, must be repeated at least ten times in order to obtain chemically pure dextrine.

Barford obtained by this method from a commercial dextrine produced by roasting, by means of a 12-fold solution and precipitation by means of alcohol, a perfectly pure dextrine; while dextrine manufactured by the action of diastase only furnished a chemically pure product by first precipitating the sulphuric acid and phosphoric acid, originating in this dextrine from the malt, by the aid of sugar of lead. The formed precipitate was filtered off, the filtrate saturated with hydro-sulphurous acid, the ensuing sulphite of lead again filtered off, and the solution thus obtained repeatedly treated with alcohol as previously described.

Quality of Dextrine; Testing of Dextrine as to its Contents of Impurities and Adulterations.

The dextrine of commerce forms mostly a white or pale-yellow colored powder, which is of more or less fineness. When bruised by squeezing between the fingers it does not grit, is tasteless, possessing a faint but very specific smell, and when exposed to damp air soon becomes moist. Sometimes it appears similar to gum-arabic in pale, yellowish or brown-yellowish, irregular-shaped pieces of various sizes being more or less lustrous. Formerly dextrine was introduced into commerce exclusively in a pulverized form; within the last decade it has been manufactured on an extensive scale in lumps. The reason for this seems to have been to give to this important product a more extensive application for those purposes of industry for which hitherto only the Arabian gum and and the Senegal gum have been applied. By imparting to dextrine the form and appearance of gum-arabic, the prejudices which were heretofore an obstacle to its use in lieu of the natural gum were thus easier removed, so that this valuable product enjoys to-day the most wide-spread propagation and application. It is furthermore noteworthy, that dextrine in pieces is preferable to that furnished in a pulverized form, because it does not ball together as the latter does when saturated with water, and hence is more readily soluble.

Dextrine appears also in commerce in a third form —as dextrine-syrup. This is a more or less pale-yellowish, transparent, tough, and glutinous mass.

Pure dextrine dissolves in water completely, leaving no residuary matter when burned, its solution reacting

neutral, being colored by iodine tincture not blue but red; and being insoluble in baryta water and tannic acid. From the alkaline copper solution of *Fehling* it reduces the peroxide of copper only after a long boiling, and finally does not discolor an alkaline solution of ferrocyanide of potash when being heated.

Since the dextrine of commerce never appears perfectly pure, and besides its contents of starch and grape-sugar it also frequently holds foreign admixtures (sand, heavy spar, gypsum), and even injurious substances resulting from the different processes of preparation, such as mineral and organic acids, it becomes in most cases imperative to submit the dextrine, prior to its application, to an accurate test.

The percentage composition of the commercial dextrine manufactured for industrial purposes can be seen from the table of analyses annexed:—

	Dextrine.	Sugar.	Insoluble substances.	Water.
Prime dextrine . .	72.45	8.77	13.14	5.64
Dark roasted starch .	70.43	1.92	19.97	7.68
Brown dextrine . .	63.60	7.67	14.51	14.23
Gommeline . . .	59.71	5.76	20.64	13.89
Older dextrine . .	49.78	1.42	30.80	18 00
Light roasted starch .	5.34	0.24	86.47	7.95

The contents of starch-sugar in dextrine are proved as follows: The aqueous solution of the dextrine to be tested is mixed and boiled with a solution of acetic oxide of copper. If starch-sugar is present, red peroxide of copper will separate in a very short time. The solution of dextrine decomposes the acetic oxide of copper, just as little as cane-sugar, gum-solution, or diluted milk-sugar solution, while the least quantity of grape-sugar will readily reduce it.

The difference between dextrine and gum-arabic

proves itself by the chemical action of these substances. The gum-arabic never contains in natural pieces any traces of grape-sugar, while the dextrine of commerce is never entirely free therefrom; hence, even the product designated as "starch-sugar free dextrine," will reduce an alkaline copper oxide solution at a heat of 80° C. (176° F.). The solution of gum-arabic is rendered turbid and white by a solution of oxalic acid, while a solution of dextrine is not affected thereby, or at least very little. A concentrated solution of gum-arabic produces, with mixtures of sesquioxide of iron, a gelatinous substance, while the solution of dextrine never does. Arabian gum, when heated with concentrated nitric acid furnishes, after the cooling off of the solution, *mucic acid*, which separates, while dextrine is thereby transformed into soluble oxalic acid.

If the point in question depends on the quantitative determination of the ingredients contained in commercial dextrine, which are soluble in water (pure dextrine and grape-sugar), such can be best accomplished, as follows:—

In the first place the contents of water are to be determined. To this end a weighed quantity of about 2 to 3 grammes (30.86 to 46.29 grains) of dextrine is to be heated in a drying-pipe (shaped like the letter U) in an oil-bath, at a temperature of 110° C. (230° F.), until it no longer suffers a reduction in weight. During the process of drying, a perfectly dry stream of air previously passed through a quantity of sulphuric acid is driven into the drying-pipe, U, and leaves the pipe ladened with moisture, and in this manner the drying of the dextrine is quickly accomplished. From the loss of weight of the weighed-off quantity of dextrine, its contents of water can be accurately calculated. For

the determination of the soluble ingredients contained in the air-dried dextrine, 50 grammes (771.50 grains) are weighed off, and mixed in 500 grammes (7715 grains) of pure distilled water. The mixture is filtered, an accurately weighed-off part of the filtrate is again evaporated and dried in a drying-tube in an oil-bath, at 110° C. (230° F.), permitting a stream of air to pass through sulphuric acid, and from thence to the drying-tube. From the weight of the perfectly dry residuum, the quantity of the previously dissolved ingredients can be calculated.

In case the contents of sugar are to be determined as to their quantity, besides the amount of soluble ingredients, Fehling's alkaline solution of copper will be best suited. 10 cubic centimetres (2.70 fluidrachms) of this solution are reduced by 0.05 gramme (0.77 grain) of starch-sugar.

Of the filtered solution of dextrine, mentioned before, so much is dropped into Fehling's copper solution, until the blue color of the mixture entirely disappears, that is, until all the soluble copper is precipitated as red peroxide of copper. From the quantity of the solution of dextrine used, the contents of sugar can easily be calculated.

Another method of determining the amount of flour, starch, and other adulterations mixed in the dextrine, is by means of the action of iodine vapors. By this treatment the following shades of color will be observed to appear: Roasted starch furnishes according to the degree of its roasting a violet, similar to that produced of white starch, or perhaps a reddish violet. Gommeline turns pale blue. Leiogomme, or roasted potato-starch, furnishes a brownish violet. Dextrine renders, according to its method of manufacture, various shades

of color. When dextrine is produced by means of *aqua regia* (nitric and muriatic acid mixed), it contains much sugar, and in this case only colors pale red brown. When prepared by means of a less potent acid, a beautiful violet ensues.

By this process of treatment, the nature and the properties of the dextrine can be tolerably well ascertained.

In conclusion, we recommend, also, the following dyer's experiments, as simple means for determining the quality of dextrine:—

1. Print an entire woollen cloth with the following color, having previously passed it through a silken sieve, steam the cloth, and after this wash it out.

1 litre (2.1 pints) of a decoction of ammoniated cochineal, prepared with 30 grammes (462.9 grains) of cochineal per litre (2.1 pints) of water;

24 grammes (370.32 grains) of powdered alum;

16 grammes (247 grains) of oxalic acid; and

375 grammes (5786 grains) dextrine (gum) powder.

If the steam color obtained is a beautiful, delicate pink, without any yellowish tinge, the dextrine may be pronounced as being superb.

2. The dextrine will touch the mordants all the more, the more aciduous it is. For this test the following light madder pink printing color is applied:—

$\frac{1}{32}$ litre (1.05 fluidounce) of sulphate of clay and potash (prepared with 36.5 grammes (563 grains) of alum per litre of water).

$\frac{15}{32}$ litre of water (= 0.98 pts.), and

250 grammes (8.75 oz. av.) of pulverized dextrine are boiled, and then stirred until completely cooled off.

When a piece of calico is dipped into this solution, it is left exposed to the air for twelve hours. After

that, such of the thickening substance and of the mordant which are not adherent to it are removed, the calico dyed in madder and soaped. A beautiful very lively pink will be the result, while if the gum is sour, sometimes nothing of the dye will remain on the cloth.

Application of Dextrine.

The uses of dextrine are very manifold, and its application in our technical industries constantly increases, it being an inexpensive substitute for the imported Senegal and Arabic gums. It is applied in the art of printing cloth for thickening and for preparing mordants for fast colors; furthermore for the thickening of several caustic colors, "*resists*" and "*reserves*," also for caustic dyes and for some "*topical colors*" on wool, cotton, and silk, as well as generally for the finishing and stiffening of textiles. For the printing of calicoes the leiogomme is even preferred in lieu of gum-arabic, since independent of its being less expensive, this dextrine has the other advantage over the natural gum of not curdling so easily with the dyes generally used for cloth printing, as is the case when gum-arabic is used. Leiogomme is usually applied in calico-printing establishments without any other admixture. Leveridge, of Massachusetts, recently took out letters patent for his method of preparing artificial gum. This article has been introduced in several calico manufactories of New England, and its preparation is compounded in the following manner, viz.:—

40 parts of sago, 55 parts of potato-starch, and 5 parts of caustic lime (finely powdered) are exposed in open vessels to a temperature not exceeding 102° C. (= 215.6° F.), until the mixture is entirely dry and

appears slightly colored. Thereupon the mass is to be heated in a closed vessel for the period of four hours, in a temperature of 162° C. (=323.6 F.). The mixture has a dark-brown color, and is, after cooling off, finely powdered.

In the paper-maker's art dextrine serves for the production of colored and tinted papers, for the glazing of cards and paper, and also for gumming envelopes, and postage and revenue stamps. It is also used for the production of pastil and gouache paintings, and for the manufacture of inks. From dextrine printing rollers and bearers are made; also the so-called "chain-dressing" for weavers' use, and sometimes it is used for lip-glue. In surgery dextrine serves as a component part in the preparation of solid bandages to be used for dressing fractures, and it also makes an excellent court-plaster. In pharmacy it serves as an admixture with the extracts of plants in order to make them applicable for being administered in powder form. For domestic purposes it is used in the preparation of bread. From 33 to 45 per cent. of dextrine can be baked with the bread without such being noticed by the consumer. The bread rises well and keeps fresh for a long time. It is likewise used for preparing fine pastry. In baking bread, the dextrine forms on its surface, in part as the crust of the bread. It furthermore forms a necessary ingredient in the brewing of beer.

The dextrine intended for cloth-printing is frequently manufactured from inferior glutinous-starch by roasting, and as the gluten thereby becomes hard and changes into a burnt mass which is insoluble in water, the dextrine thus made impure becomes useless as a means for thickening. The burnt gluten easily clogs or fills up the engraving of the cylinders in roller-

printing, and causes the gumlike printing color to become so tough that no sharp impression can be obtained. In order to remove these defects the following manipulation is recommended, by means of which the commercial dextrine may be tested at once, without difficulty, with regard to its contents of burnt gluten.

According to the recipe, prepared by *Bremer*, one part of the dextrine to be tested is mixed with one part of water of 60° C. (140° F.). The solution thus obtained is again mixed in five parts of water of the same temperature. This preparation is left at rest, undisturbed for twenty-four hours, during which time the burnt gluten puffs up, without dissolving or even thickening the liquid, and deposits on the bottom. The greater the contents of burnt gluten in either dextrine or leiogomme the less suitable are they for application as a means for thickening or weighting textile fabrics.

Plan for the Establishment of a Potato-starch and Dextrine Manufactory.—In Fig. 52 is delineated a sketch of an establishment both for starch and dextrine manufacturing. This sketch represents the latest improvements and inventions in this branch of industry. The arrangement of the plan is visible from the sketch, and hence but little remains to be elucidated.

This potato-starch and dextrine manufactory having all the arrangements and machinery for the manipulation of from 15,000 to 20,000 kilogrammes (33,000 to 44,000 lbs.) of potatoes per day, consists of the following different parts, which are all arranged in the most suitable manner:—

1, A spacious vaulted cellar for receiving and storing away from 150,000 to 200,000 kilogrammes (330,000 to 440,000 lbs.) of potatoes; 2, hall for machinery and

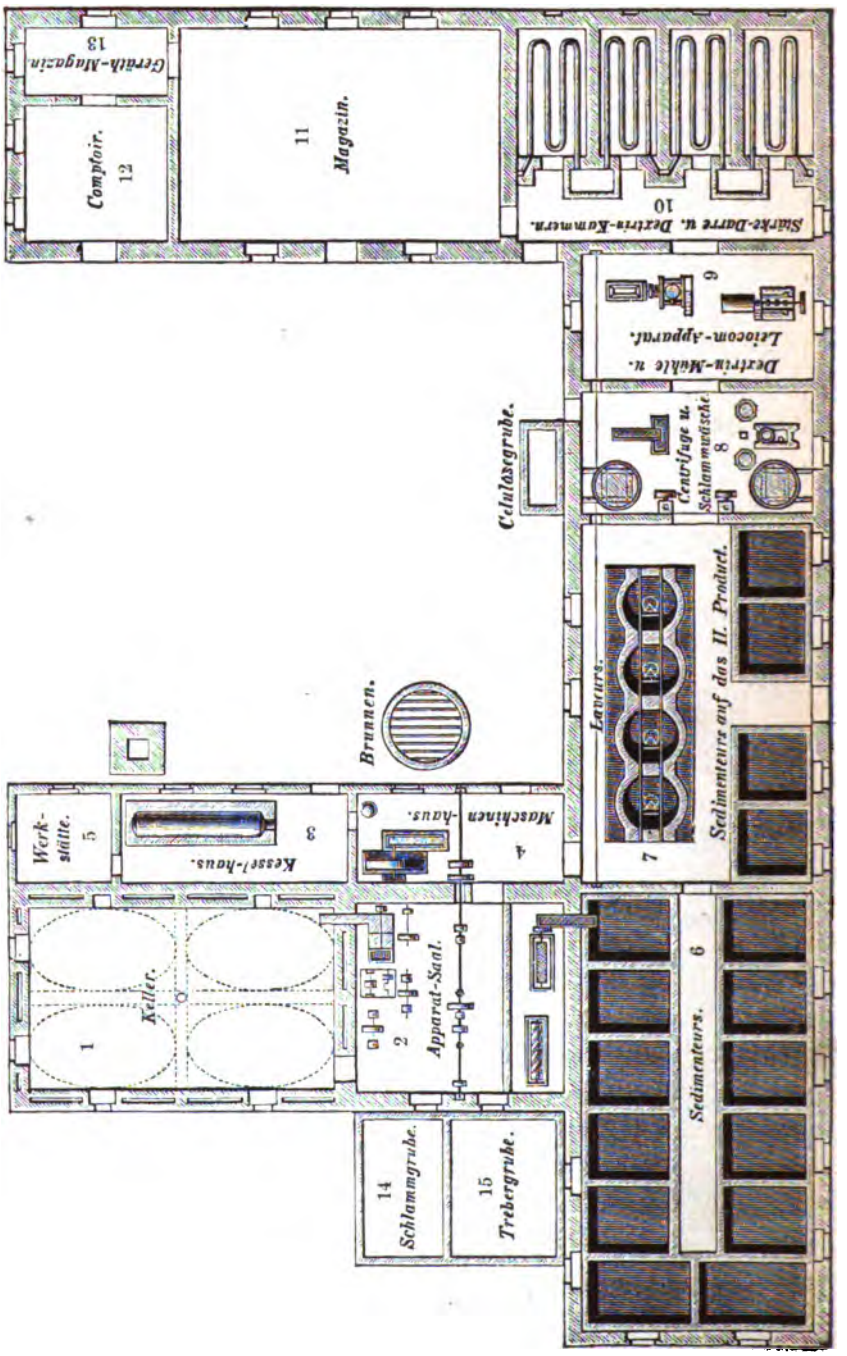


Fig. 52.

Potato-starch and dextrine manufactory, with the latest improvements.

apparatus; 3, boiler-house; 4, engine-house; 5, work-shop for repairs; 6, room for the "sedimenteurs" (settling tanks); 7, room for the laveurs; 8, room for the centrifugal-machine; 9, room for producing the leiogomme; 10, dextrine chambers; 11, warehouse; 12, office; 13, tool-room.

Outside of these buildings there are: 1, the scum-pit (14); 2, the pit for the residuum of grains, offal, and albumen (15).

For the making of starch the following course of operation is observed in this establishment, to wit:—

An elevator, with endless chain, carries the potatoes from the cellar to the washing machine, which is mounted in a corner of the hall; 1500 to 2000 kilogrammes (3300 to 4400 lbs.) of potatoes are thus raised per hour.

The construction of this washing-machine, as also the mechanism of all the other machinery, apparatus, and contrivances, has been described in the foregoing pages of this treatise.

The general principle on which the drying-rooms are constructed is entirely identical with those of the malt-kilns, a ventilation resembling Venitian blinds being used.

The roasting apparatus and the dextrine-mill are placed in a separate room, as represented in the drawing, and are situated between the room for the centrifugal apparatus and the dextrine chambers.

In conclusion it may be stated that by this method and machinery 120 kilogrammes (264 lbs.) of starch will make 100 kilogrammes (220 lbs.) of excellent dextrine.

In the manufacture of starch in this establishment, the following *modus operandi* is observed: A

chain-pumpwork carries the potatoes from the cellar to the washing-machine, which is placed in the same room with the grater. From 1500 to 2000 kilogrammes (3300 to 4400 lbs.) per hour, or 25 to 33 kilogrammes (55 to 72.6 lbs.) per minute of potatoes are thus hoisted up. The construction of this washing apparatus has been fully described; its capacity is 25 revolutions per minute. The perfectly cleansed potatoes roll over an inclined plane to the potato grater, which makes 900 to 1000 revolutions a minute, while the driving machine executes from 90 to 100 strokes per minute. The water supply, by which the grater is fed, amounts to 40 litres (10.56 gallons) per hour. A pump, making 30 strokes per minute, carries the fine potato-paste to the extraction machine. The brush-cylinders make 24 to 30 revolutions per minute, and the water supply of this apparatus amounts to from 300 to 350 litres (79.2 to 92.4 gallons) per minute. The starch-milk extracted runs from thence upon the repassing-sieve, and the shaking-sieve, and from there into the "sedimenteurs" (settling tanks), which have a capacity of 20,000 kilogrammes (44,000 lbs.) of starch-milk, the quantity manufactured per day.

The washing water resulting from the cleaning of the potatoes runs through a subterranean culvert into the scum-pit, where the solid—mostly earthy—parts are settling, and which furnish an excellent fertilizer. The pulp thrown out by the extracting machine, the repassing- and shaking-sieves, is collected in the return-pit, and furnishes a food for domestic animals.

In the room for the starch-washing apparatus are four laveurs (wash drums), three of them serving for the reception of the first product, while the fourth is designed to receive the starch phlegm. When the

starch in the sedimenteurs has settled, the water above the starch is conducted by means of an elastic siphon to the albumen sink, which is of a corresponding size to the requirements of the factory. The albumen is precipitated by the application of lime-milk, and after its setting the water above it is drained off.

The starch in the sedimenteur is then placed in the laveur, where it is washed out with pure water. The process of washing being done, and the starch left to settle, the water above it is removed by a siphon, and the separating of the starch from the scum-layer above it is attended to.

For the reception and other manipulation of the starch-phlegm one and the same laveur serves, and in it the starch is mixed with water, then pumped up by means of a pump into the stirring-tub, and from thence conducted to a shaking-sieve, which is placed in the same room in which the centrifugal apparatus is mounted. The milk running off from this sieve runs into the sedimenteurs for furnishing the second product, four of which are placed in a room. Here the depositing of the starch takes place, while the separated cellulose is carried to the cellulose-pit. The starch, freed of its phlegm-layer, is again washed once or twice, thereupon mixed up to a dense starch-milk, and by means of another pump lifted into the stirring-tub, now to be conducted to the centrifugal apparatus.

If the product is to be disposed of as starch, or for the manufacture of dextrine, the starch after having passed the centrifugal machine is expedited to the drying rooms, which consist of four chambers, and are also used for the manufacture of dextrine.

In producing dextrine, the starch is previously pre-

pared by a diluted mineral acid. This is manipulated by manual labor in the so-called mixing troughs. But as this dough is very stiff, the equal kneading of the starch with the sour-water is a laborious job, and hence kneading machines may be profitably applied for this purpose.

APPENDIX.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

THE United States being the first to introduce the decimal system into the coinage of the country, and to demonstrate its superior utility, it is remarkable that we have hesitated so long in regard to the substitution of the same simple and rational system of weights and measures for the complicated and confused standards in general use.

In May, 1866, the Committee on Coinage, Weights, and Measures presented to the House of Representatives an exhaustive report, accompanied by bills authorizing the introduction of the *metric system* into the various departments of trade, and making all contracts, based on this system of weights and measures, valid before any court in the United States. They said:—

"THE METRIC SYSTEM.

"It is orderly, simple, and perfectly harmonious, having useful relations between all its parts. It is based on the METER, which is the principal and only arbitrary unit. The meter is a measure of length, and was intended to be, and is, very nearly one ten-millionth of the distance on the earth's surface from the equator to the pole. It is 39.37 inches, very nearly.

"The *are* is a surface equal to a square whose side is 10 meters. It is nearly four square rods.

"The *liter* is the unit for measuring capacity, and is equal to the contents of a cube whose edge is a tenth part of the meter. It is a little more than a wine quart.

"The *gramme* is the unit of weight, and is the weight of a cube of water, each edge of the cube being one one-hundredth of the meter. It is equal to 15.432 grains.

"The *stere* is the cubic meter.

"Each of these units is divided decimally, and larger units are formed by multiples of 10, 100, &c. The successive multiples are designated by the prefixes, *deka*, *hecto*, *kilo*, and *myria*; the subordinate parts by *deci*, *centi*, and *milli*, each having its own numerical significance.

"The nomenclature, simple as it is in theory, and designed

from its origin to be universal, can only become familiar by use. Like all strange words, these will become familiar by custom, and obtain popular abbreviations. A system which has incorporated with itself so many different series of weights, and such a nomenclature as 'scruples,' 'pennyweights,' 'avoirdupois,' and with no invariable component word, can hardly protest against a nomenclature whose leading characteristic is a short component word with a prefix signifying number. We are all familiar with *thermometer*, *barometer*, *diameter*, *gasometer*, &c., with *telegram*, *monogram*, &c., words formed in the same manner.

"After considering every argument for a change of nomenclature, your committee have come to the conclusion that any attempt to conform it to that in present use would lead to confusion of weights and measures, would violate the early learned order and simplicity of metric denomination, and would seriously interfere with that universality of system so essential to international and commercial convenience.

"When it is remembered that of the value of our exports and imports, in the year ending June 30, 1860, in all $762,000,000, the amount of near $700,000,000 was with nations and their dependencies that have now authorized, or taken the preliminary steps to authorize, the metric system, even denominational uniformity for the use of accountants in such vast transactions assumes an important significance. In words of such universal employment, each word should represent the identical thing intended, and no other, and the law of association familiarizes it.

"Your committee unanimously recommend the passage of the bills and joint resolutions appended to this report. . . . . The metric system is already used in some arts and trades in this country, and is especially adapted to the wants of others. Some of its measures are already manufactured at Bangor, in Maine, to meet an existing demand at home and abroad. The manufacturers of the well-known Fairbanks' scales state: 'For many years we have had a large export demand for our scales with French weights, and the demand and sale are constantly increasing.' Its minute and exact divisions specially adapt it to the use of chemists, apothecaries, the finer operations of the artisan and to all scientific objects. It has always been and is now used in the United States coast survey. Yet in some of the States, owing to the phraseology of their laws, it would be a direct violation of them to use it in the business transactions of the community. It is, therefore, very important to legalize its use, and to give to the people, or that portion of them desiring it, the opportunity for its legal employment, while the knowledge of its characteristics will be thus diffused among men."

WEIGHTS AND MEASURES.

APOTHECARIES' WEIGHT, U. S.

Pound.		Ounces.		Drachms.		Scruples.		Grains.
lb 1	=	12	=	96	=	288	=	5760
		℥ 1	=	8	=	24	=	480
				ʒ 1	=	3	=	60
						℈ 1	=	gr. 20

The imperial standard Troy weight, at present recognized by the British laws, corresponds with the apothecaries' weight in pounds, ounces, and grains, but differs from it in the division of the ounce, which, according to the former scale, contains twenty pennyweights, each weighing twenty-four grains.

AVOIRDUPOIS WEIGHT.

Pound.		Ounces.		Drachms.		Troy grains.
lb 1	=	16	=	256	=	7000.
		oz. 1	=	16	=	437.5
				dr. 1	=	27.34375

Relative Value of Troy and Avoirdupois Weights.

Pound.		Pounds.	Pound.	Oz.	Grains.
1 Troy	=	0.822857 Avoirdupois =	0	13	72.5
1 Avoirdupois	=	1.215277 Troy =	1	2	280.

WINE MEASURE, U. S.

Gallon.		Pints.		Fluidounces.		Fluidrachms.		Minims.		Cubic inches.
Cong. 1	=	8	=	128	=	1024	=	61440	=	231.
		O 1	=	16	=	128	=	7680	=	28.875
				f℥ 1	=	8	=	480	=	1.8047
						f℥ 1	=	♏ 60	=	0.2256

IMPERIAL MEASURE.

Adopted by all the British Colleges.

Gallon.		Pints.		Fluidounces.		Fluidrachms.		Minims.
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

Relative Value of Apothecaries' and Imperial Measures.

APOTHECARIES' MEASURE.		IMPERIAL MEASURE. Pints.	Fluidozs.	Fluidrms.	Minims.
1 gallon	=	6	13	2	23
1 pint	=		16	5	18
1 fluidounce	=		1	0	20
1 fluidrachm	=			1	2.5
1 minim	=				1.04

IMPERIAL MEASURE.		APOTHECARIES' MEASURE. Gallon.	Pints.	Fluidoz.	Fluidrms.	Minims
1 gallon	=	1	1	9	5	8
1 pint	=		1	3	1	38
1 fluidounce	=				7	41
1 fluidrachm	=					58
1 minim	=					0.96

Relative Value of Weights and Measures in Distilled Water at 60° Fahr.

1. Value of Apothecaries' Weight in Apothecaries' Measure.

			Pints.	Fluidoz.	Fluidr.	Minims.
1 pound	= 0.7900031 pints	=	0	12	5	7.2238
1 ounce	= 1.0533376 fluidounces	=	0	1	0	25.6020
1 drachm	= 1.0533376 fluidrachms	=	0	0	1	3.2002
1 scruple	=		0	0	0	21 0667
1 grain	=		0	0	0	1.0533

2. Value of Apothecaries' Measure in Apothecaries' Weight.

		Pounds.	Oz.	Dr.	Sc.	Gr.	Grains.
1 gallon	= 10.12654270 pounds	= 10	1	4	0	8.88	= 58328.886
1 pint	= 1.26581783 pounds	= 1	3	1	1	11.11	= 7291.1107
I fluidounce	= 0.94936332 ounces	= 0	0	7	1	15.69	= 455.6944
1 fluidrachm	= 0.94936332 drms.	= 0	0	0	2	16.96	= 56.9618
1 minim	= 0.94936332 grains	=					1.9493

3. Value of Avoirdupois Weight in Apothecaries' Measure.

		Pints.	Fluidoss.	Fluidrms.	Minims.
1 pound	= 0.9600732 pints	= 0	15	2	53.3623
1 ounce	= 0.9600732 fluidounces	= 0	0	7	40.8351

4. Value of Apothecaries' Measure in Avoirdupois Weight.

1 gallon = 8.33269800 pounds.
1 pint = 1.04158725 pounds.
1 fluidounce = 1.04158725 ounces.

5. Value of Imperial Measure in Apothecaries' and Avoirdupois Weights.

Imperial Measure.	Apothecaries' Weight.	Avoirdupois Weight.	Grains.	Cubic inches.
1 gallon	= 12 lb 1 ℥ 6 ʒ 2 ℈ 0 gr.	= 10 lb 0 ℥	=70,000	=277.27384
1 pint	= 1 6 1 2 10	= 1 4	= 8,750	= 34.65923
1 fluidounce	= 7 0 17.5	= 1	= 437.5	= 1.73296
1 fluidrachm	= 2 14.69	=	54.69	= 0.21662
1 minim	=		0.91	= 0.00361

In converting the weights of liquids heavier or lighter than water into measures, or conversely, a correction must be made for specific gravity. In converting weights into measures, the calculator may proceed as if the liquid was water, and the obtained measure will be the true measure *inversely* as the specific gravity. In the converse operation, of turning measures into weights, the same assumption may be made, and the obtained weight will be the true weight *directly* as the specific gravity.

TABLES

SHOWING THE

RELATIVE VALUES OF FRENCH AND ENGLISH WEIGHTS AND MEASURES, &c.

Measures of Length.

Millimetre	=	0.03937	inch.
Centimetre	=	0.393708	"
Decimetre	=	3.937079	inches.
Metre	=	39.37079	"
"	=	3.2808992	feet.
"	=	1.093633	yard.
Decametre	=	32.808992	feet.
Hectometre	=	328.08992	"
Kilometre	=	3280.8992	"
"	=	1093.633	yards.
Myriametre	=	10936.33	"
"	=	6.2138	miles.
Inch ($\frac{1}{36}$ yard)	=	2.539954	centimetres.
Foot ($\frac{1}{3}$ yard)	=	3.0479449	decimetres.
Yard	=	0.91438348	metre.
Fathom (2 yards)	=	1.82876696	"
Pole or perch ($5\frac{1}{2}$ yards)	=	5.029109	metres.
Furlong (220 yards)	=	201.16437	"
Mile (1760 yards)	=	1609.3149	"
Nautical mile	=	1852	"

Superficial Measures.

Square millimetre	=	$\frac{1}{645}$	square	inch.
" "	=	0.00155	"	"
" centimetre	=	0.155006	"	"
" decimetre	=	15.50059	"	inches.
" "	=	0.107643	"	foot.
" metre or centiare	=	1550.05989	"	inches.
" " "	=	10.764299	"	feet.
" " "	=	1.196033	"	yard
Are	=	1076.4299	"	feet.
"	=	119.6033	"	yards.
"	=	0.098845	rood.	
Hectare	=	11960.3326	square	yards.
"	=	2.471143	acres.	
Square inch	=	645.109201	square	millimetres.
" "	=	6.451367	"	centimetres
" foot	=	9.289968	"	decimetres.
" yard	=	0.836097	"	metre.
" rod or perch	=	25.291939	"	metres.
Rood (1210 sq. yards)	=	10.116775	ares.	
Acre (4840 sq. yards)	=	0.404671	hectare.	

Measures of Capacity.

Cubic millimetre	=	0.000061027	cubic	inch.
" centimetre or millilitre	=	0.061027	"	"
10 " centimetres or centilitre	=	0.61027	"	"
100 " " " decilitre	=	6.102705	"	inches.
1000 " " " litre	=	61.0270515	"	"
" " " " "	=	1.760773	imp'l	pint.
" " " " "	=	0.2200967	"	gal'n.
Decalitre	=	610.270515	cubic	inches.
"	=	2.2009668	imp.	gal'ns.
Hectolitre	=	3.531658	cubic	feet.
"	=	22.009668	imp.	gal'ns.
Cubic metre or stere or kilolitre	=	1.30802	cubic	yard.
" " "	=	35.3165807	"	feet.
Myrialitre	=	353.165807	"	"

Cubic inch	=	16.386176	cubic centimetres.
" foot	=	28.315312	" decimetres.
" yard	=	0.764513422	" metre.

American Measures.

Winchester or U.S. gallon (231 cub.in.)	=	3.785209	litres.
" " bushel(2150.42 cub. in.)	=	35.23719	"
Chaldron (57.25 cubic feet)	=	1621.085	"

British Imperial Measures.

Gill	=	0.141983	litre.
Pint (⅛ gallon)	=	0.567932	"
Quart (¼ gallon)	=	1.135864	"
Imperial gallon (277.2738 cub. in.)	=	4.54345797	litres.
Peck (2 gallons)	=	9.0869159	"
Bushel (8 gallons)	=	36.347664	"
Sack (3 bushels)	=	1.09043	hectolitre.
Quarter (8 bushels)	=	2.907813	hectolitres.
Chaldron (12 sacks)	=	13.08516	"

Weights.

Milligramme	=	0.015438395	troy grain.
Centigramme	=	0.15438395	" "
Decigramme	=	1.5438395	" "
Gramme	=	15.438395	" grains.
"	=	0.643	pennyweight.
"	=	0.0321633	oz. troy.
"	=	0.0352889	oz. avoirdupois.
Decagramme	=	154.38395	troy grains.
"	=	5.64	drachms avoirdupois.
Hectogramme	=	3.21633	oz. troy.
"	=	3.52889	oz. avoirdupois.
Kilogramme	=	2.6803	lbs. troy.
"	=	2.205486	lbs. avoirdupois.
Myriagramme	=	26.803	lbs. troy.
"	=	22.05486	lbs. avoirdupois.

Quintal metrique = 100 kilog. = 220.5486 lbs. avoirdupois.
Tonne = 1000 kilog. = 2205.486 " "

Different authors give the following values for the gramme:—

Gramme = 15.44402 troy grains.
" = 15.44242 "
" = 15.4402 "
" = 15.433159 "
" = 15.43234874 "

AVOIRDUPOIS.

Long ton = 20 cwt. = 2240 lbs.	=	1015.649	kilogrammes.
Short ton (2000 lbs.)	=	906.8296	"
Hundred weight (112 lbs.)	=	50.78245	"
Quarter (28 lbs.)	=	12.6956144	"
Pound = 16 oz. = 7000 grs.	=	453.4148	grammes.
Ounce = 16 dr'ms. = 437.5 grs.	=	28.3375	"
Drachm = 27.344 grains	=	1.77108	gramme.

TROY (PRECIOUS METALS).

Pound = 12 oz. = 5760 grs.	=	373.096	grammes.
Ounce = 20 dwt. = 480 grs.	=	31.0913	"
Pennyweight = 24 grs.	=	1.55457	gramme.
Grain	=	0.064773	"

APOTHECARIES' (PHARMACY).

Ounce = 8 drachms = 480 grs.	=	31.0913	gramme.
Drachm = 3 scruples = 60 grs.	=	3.8869	"
Scruple = 20 grs.	=	1.29546	gramme.

CARAT WEIGHT FOR DIAMONDS.

1 carat = 4 carat grains = 64 carat parts.
" = 3.2 troy grains.
" = 3.273 " "
" = 0.207264 gramme
" = 0.212 "
" = 0.205 "
Great diversity in value.

Proposed Symbols for Abbreviations.

M—myria — 10000	Mm	Mg	Ml	
K—kilo — 1000	Km	Kg	Kl	
H—hecto — 100	Hm	Hg	Hl	Ha
D—deca — 10	Dm	Dg	Dl	Da
Unit — 1	metre—m	gramme—g	litre—l	are—a
d—deci — 0.1	dm	dg	dl	da
c—centi — 0.01	cm	cg	cl	ca
m—milli — 0.001	mm	mg	ml	

Km = Kilometre. Hl = Hectolitre. cg = centigramme. c. cm = $\overline{cm}^3$ = cubic centimetre. $\overline{dm}^2$ = sq. dm = square decimetre. Kgm = Kilogrammetre. Kg° = Kilogramme degree.

Celsius or Centigrade.	Fahrenheit.	Réaumur.
— 15°	+ 5°	— 12°
— 10	+ 14	— 8
— 5	+ 23	— 4
0 melting	+ 32	ice 0
+ 5	+ 41	+ 4
+ 10	+ 50	+ 8
+ 15	+ 59	+ 12
+ 20	+ 68	+ 16
+ 25	+ 77	+ 20
+ 30	+ 86	+ 24
+ 35	+ 95	+ 28
+ 40	+104	+ 32
+ 45	+113	+ 36
+ 50	+122	+ 40
+ 55	+131	+ 44
+ 60	+140	+ 48
+ 65	+149	+ 52
+ 70	+158	+ 56
+ 75	+167	+ 60
+ 80	+176	+ 64
+ 85	+185	+ 68
+ 90	+194	+ 72
+ 95	+203	+ 76
+100 boiling	+212	water + 80
+200	+392	+160
+300	+572	+240
+400	+752	+320
+500	+932	+400

1° C. = 1°.8 Ft. = $\frac{9}{5}$° Ft. = 0°.3 R. = $\frac{4}{5}$° R.

1° C. × $\frac{9}{5}$ = 1° Ft. 1° Ft. × $\frac{5}{9}$ = 1° C. 1° R. × $\frac{9}{4}$ = 1° Ft.

1° C. × $\frac{4}{5}$ = 1° R. 1° Ft. × $\frac{5}{9}$ = 1° R. 1° R. × $\frac{5}{4}$ = 1° C.

Calorie (French) = unit of heat = kilogramme degree } English.

It is the quantity of heat necessary to raise 1° C. the temperature of 1 kilogramme of distilled water.

Kilogrammetre = Kgm = the power necessary to raise 1 kilogramme, 1 metre high, in one second. It is equal to $\frac{1}{75}$ of a French horse power. An English horse power = 550 foot pounds, while a French horse power = 542.7 foot pounds.

Ready-made Calculations.

No. of units.	Inches to centimetres.	Feet to metres.	Yards to metres.	Miles to Kilometres.	Millimetres to inches.
1	2.53995	0.3047945	0.91438348	1.6093	0.03937079
2	5.0799	0.6095890	1.82876696	3.2186	0.07874158
3	7.6199	0.9143835	2.74315044	4.8279	0.11811237
4	10.1598	1.2197680	3.65753392	6.4373	0.15748316
5	12.6998	1.5239724	4.57191740	8.0466	0.19685395
6	15.2397	1.8287669	5.48630088	9.6559	0.23622474
7	17.7797	2.1335614	6.40068436	11.2652	0.27559553
8	20.3196	2.4383559	7.31506784	12.8745	0.31496632
9	22.8596	2.7431504	8.22945132	14.4838	0.35433711
10	25.3995	3.0479450	9.14383480	16.0930	0.39370790

No. of units.	Centimetres to inches.	Metres to feet.	Metres to yards.	Kilometres to miles.	Square inches to square centimetres.
1	0.3937079	3.2808992	1.093633	0.6213824	6.45136
2	0.7874158	6.5617984	2.187266	1.2427648	12.90272
3	1.1811237	9.8426976	3.280899	1.8641472	19.35408
4	1.5748316	13 1235968	4.374532	2.4855296	25.80544
5	1.9685395	16.4044960	5.468165	3.1069120	32.25680
6	2.3622474	19.6853952	6.561798	3.7282944	38.70816
7	2.7559553	22.9662944	7.655431	4.3496768	45.15952
8	3.1496632	26.2471936	8.749064	4.9710592	51.61088
9	3.5433711	29.5280928	9.842697	5.5924416	58.06224
10	3.9370790	32.8089920	10.936330	6.2138240	64.51360

No. of units.	Square feet to sq. metres.	Sq. yards to sq. metres.	Acres to hectares.	Square centimetres to sq. inches.	Sq. metres to sq. feet.
1	0.0929	0.836097	0.404671	0.155	10.7643
2	0.1858	1.672194	0.809342	0.310	21.5286
3	0.2787	2.508291	1.204013	0.465	32.2929
4	0.3716	3.344388	1.618684	0.620	43.0572
5	0.4645	4.180485	2.023355	0.775	53.8215
6	0.5574	5.016582	2.428026	0.930	64.5858
7	0.6503	5.852679	2.832697	1.085	75.3501
8	0.7432	6.688776	3.237368	1.240	86.1144
9	0.8361	7.524873	3.642039	1.395	96.8787
10	0.9290	8.360970	4.046710	1.550	107.6430

No. of units.	Square metres to sq. yards.	Hectares to acres.	Cubic inches to cubic centimetres.	Cubic feet to cubic metres.	Cubic yards to cubic metres.
1	1.196033	2.471143	16.3855	0.02831	0.76451
2	2.392066	4.942286	32.7710	0.05662	1.52902
3	3.588099	7.413429	49.1565	0.08494	2.29354
4	4.784132	9.884572	65.5420	0.11325	3.05805
5	5.980165	12.355715	81.9275	0.14157	3.82257
6	7.176198	14.826858	98.3130	0.16988	4.58708
7	8.372231	17.298001	114.6985	0.19819	5.35159
8	9.568264	19.769144	131.0840	0.22651	6.11611
9	10.764297	22.240287	147.4695	0.25482	6.88062
10	11.960330	24.711430	163.8550	0.28315	7.64513

No. of units.	Cubic centimetres to cubic inches.	Litres to cubic inches.	Hectolitres to cubic feet.	Cubic metres to cubic feet.	Cubic metres to cubic yards.
1	0.06102	61.02705	3.5317	35.31659	1.30802
2	0.12205	122.05410	7.0634	70.63318	2.61604
3	0.18308	183.08115	10.5951	105.94977	3.92406
4	0.24411	244.10820	14.1268	141.26636	5.23208
5	0.30514	305.13525	17.6585	176.58295	6.54010
6	0.36617	366.16230	21.1902	211.89954	7.84812
7	0.42720	427.18935	24.7219	247.21613	9.15614
8	0.48823	488.21640	28.2536	282.53272	10.46416
9	0.54926	549.24345	31.7853	317.84931	11.77218
10	0.61027	610.27050	35.3166	353.16590	13.08020

No. of units.	Grains to grammes.	Ounces avoir. to grammes.	Ounces troy to grammes.	Pounds avoir. to kilogrammes.	Pounds troy to kilogrammes.
1	0.064773	28.3375	31.0913	0.4534148	0.373096
2	0.129546	56.6750	62.1826	0.9068296	0.746192
3	0.194319	85.0125	93.2739	1.3602444	1.119288
4	0.259092	113.3500	124.3652	1.8136592	1.492384
5	0.323865	141.6871	155.4565	2.2670740	1.865480
6	0.388638	170.0250	186.5478	2.7204888	2.238576
7	0.453411	198.3625	217.6391	3.1739036	2.611672
8	0.518184	226.7000	248.7304	3.6273184	2.984768
9	0.582957	255.0375	279.8217	4.0807332	3.357864
10	0.647730	283.3750	310.9130	4.5341480	3.730960

No. of units.	Long tons to tonnes of 1000 kilog.	Pounds per square inch to kilogrammes per square centimetre.	Grammes to grains.	Grammes to ounces avoir.	Grammes to ounces troy.
1	1.015649	0.0702774	15.438395	0.0352889	0.0321633
2	2.031298	0.1405548	30.876790	0.0705778	0.0643266
3	3.046947	0.2108322	46.315185	0.1058667	0.0964899
4	4.062596	0.2811096	61.753580	0.1411556	0.1286532
5	5.078245	0.3513870	77.191975	0.1764445	0.1608165
6	6.093894	0.4216644	92.630370	0.2117334	0.1929798
7	7.109543	0.4919418	108.068765	0.2470223	0.2251431
8	8.125192	0.5622192	123.507160	0.2823112	0.2573064
9	9.140841	0.6324966	138.945555	0.3176001	0.2894697
10	10.156490	0.7027740	154.383950	0.3528890	0.3216330

No. of units.	Kilogrammes to pounds avoirdupois.	Kilogrammes to pounds troy.	Metric tonnes of 1000 kilog. to long tons of 2240 pounds.	Kilog. per square millimetre to pounds per square inch.	Kilog. per square centimetre to pounds per square inch.
1	2.205486	2.6803	0.9845919	1422.52	14.22526
2	4.410972	5.3606	1.9691838	2845.05	28.45052
3	6.616458	8.0409	2.9537757	4267.57	42.67578
4	8.821944	10.7212	3.9383676	5690.10	56.90104
5	11.027430	13.4015	4.9229595	7112.63	71.12630
6	13.232916	16.0818	5.9075514	8535.15	85.35156
7	15.438402	18.7621	6.8921433	9957.68	99.57682
8	17.643888	21.4424	7.8767352	11380.20	113.80208
9	19.849374	24.1227	8.8613271	12802.73	128.02734
10	22.054860	26.8030	9.8459190	14225.26	142.25260

HYDROMETERS AND THERMOMETERS.

An areometer is a convenient glass instrument for measuring the density or specific gravity of fluids. Areometer and hydrometer are synonymous terms, the first being derived from the Greek words αραιός, *rare*, and μετρον, *measure;* and the latter from ὑδωρ, *water*, and μετρον, *measure;* hence the same instrument is frequently denominated both hydrometer and areometer. This apparatus is often referred to throughout this work; for instance, in speaking of alcohol, or lye, their strength is stated as being of so many degrees (17° or 36°) Baumé, that is, its force or value is of that specific gravity, corresponding with the degree to which the hydrometer sinks in either the alcohol or alkaline solution. But, for those liquids lighter or rarer than water, viz., alcohol, ethers, etc., the scale is graduated differently than for the heavier or more dense, examples of which are the acids, saline solutions, syrups, and the like. There are several kinds of hydrometers; but that called Baumé's is the most used, and to this our remarks are applied.

They are blown out of a piece of slender glass tubing, and of the form shown by Figs. 53 and 54; A being the stem containing the

Fig. 53.

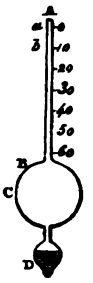
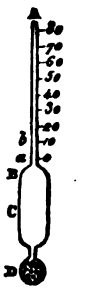


Fig. 54.



graduated paper scale, B the bulb portion, and D the small globes containing mercury or shot, serving as ballast to maintain the instrument in an upright position, when it is placed in a liquid.

The graduation is accomplished by plunging it into distilled water of 58° F., and weighting the globe with shot or mercury, until the instrument sinks to the line *a*, which is its zero point. This zero point thus determined is to be marked accurately upon

the glass or its accompanying paper scale, and the instrument again plunged into ninety parts of distilled water, holding in solution ten parts of previously dried chloride of sodium or common salt. The point to which it sinks in this liquid, say *b*, for instance, is then also marked carefully upon the scale, and rated as ten compared with its zero point. The interval between these two points is then spaced off into ten equal divisions, according to which the remainder of the tube is graduated so that each degree is intended to represent a density corresponding to one per cent. of the salt.

The above mode of graduating refers to the hydrometer for liquids denser than water, but that for the liquids rarer than water is a little different from the preceding in form, and necessarily has a modified scale, which is graduated as is shown by Fig. 54. The instrument should be sufficiently heavy in ballast to sink in a saline solution of ten parts of dried chloride of sodium in ninety parts distilled water to the bottom of its stem *a*, to be marked as the zero of the scale.

Now, when it is again placed in distilled water alone, it floats or sinks to a point somewhere about *b*, which is to be the ten degree mark. The rest of the stem is then to be accurately divided into as many ten degree intervals as its length will permit, and each subdivision into ten uniform smaller degrees or intervals.

Fig. 55.

As it would be troublesome, and with many impracticable, to estimate the specific gravities of their liquids in a scientific way, these little instruments are a great convenience, for by taking out a portion of the fluid to be tested, and placing it in a glass cylinder, Fig. 55, its degree Baumé may be ascertained by noting the point to which a hydrometer sinks therein, and afterwards its specific gravity, by comparing that with its corresponding degree in the table. For instance, suppose the hydrometer sinks in alcohol to 35°, then its specific gravity is 0.8538, and this again can be translated into its absolute spirit strength by comparison with any accurately calculated alcohol tables. So, also, if a hydrometer for liquids denser than water sinks in lye to 26°, it denotes that the lye has a specific gravity of

1.2268. The presence of foreign matters will cause the hydrometer to give a false indication, and it is, therefore, necessary, when lyes contain impurities, to follow special directions, to ascertain their amount of caustic alkali. When the lye is nearly pure, they answer satisfactorily; and, indeed, under all circumstances, they serve very well for noting a progressive increase or diminution in the strength of lyes or other liquids. The temperature of the liquid should be 58° to 60° F., at the moment of testing it.

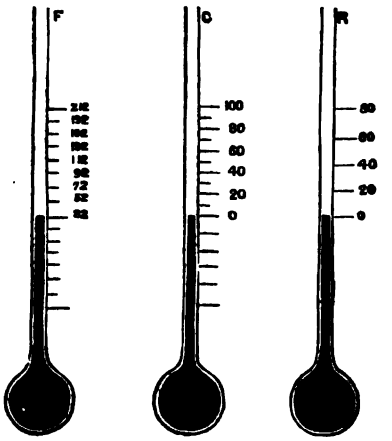
Thermometers.—The thermometer is an instrument made of glass exclusively, when intended for practical purposes. Fig. 56 shows one with the scale of Fahrenheit, graduated on the glass, so that, when having been dipped in liquids, it may be easily cleansed. It derives its name from two Greek words, θερμος, *warm*, and μετρον, *measure*, and is, as its title indicates, a measurer of the variation of temperature in bodies. The principle upon which it is constructed, "is the change of volume which takes place in bodies, when their temperature undergoes an alteration, or, in other words, upon their expansion." As it is necessary, in the construction of thermometers, that the material used to measure the change of temperature shall be of uniform expansion, and with a very distant interval between its freezing and boiling point, as fulfilling these requisites better than any other body, metallic mercury is generally used. There are several different thermometrical scales, all constructed upon the same principle, but varying in their graduation; the boiling and freezing points of each, though corresponding in fact, being represented by different numbers. The Fahrenheit scale is most used in this country; that of Celsius, called the Centigrade, in France and the Continent generally, except Spain and Germany, where Reaumur's scale is preferred. The relation between the three scales is shown by Fig. 57. The Fahrenheit scale is most convenient, because of the lesser value of its divisions.

Fig. 56.

In the graduation of the scale, it is only necessary to have two fixed determinate temperatures, and for these the boiling and freezing points of water are universally chosen. The scales can be extended beyond either of these points, by continuing the

graduation. Those degrees below zero or 0° have the minus (—) prefixed, to distinguish them from those above; thus, 55° F. means fifty-five degrees above zero, Fahrenheit's scale, and —9° C., nine

Fig. 57.



degrees below zero, Centigrade scale. The thermometers for general use very seldom, however, extend either way beyond the boiling and freezing points of water, but for manufacturers' use they are graduated sometimes to 400° or 600°.

Centigrade and Fahrenheit.—In the Fahrenheit thermometer the number 0° on the scale corresponds to the temperature of a mixture of salt and ice—the greatest degree of cold that could be artificially produced when the thermometer was originally introduced; 32° (freezing point) corresponds to the temperature of melting ice; and 212° to the temperature of pure boiling water—in both cases, under the ordinary atmospheric pressure of 14.7 pounds per square inch. Each division of the (this) thermometer represents 1° Fah., and between 32° and 212° there are 180°. In the Cent. thermometer, used universally in scientific investigations, 1° corresponds to melting ice, and 100° to boiling water. From the freezing to the boiling point there are 100°.

The accompanying table shows the relation of the Centigrade and Fahrenheit thermometer scales, 5° C. being equal to 9° F., because the interval between the freezing and boiling points of water is divided into 100 and 180 equal parts, and these numbers

are respectively multiples of, or 20 times 5 and 9. If the superfluous 32° on the F. side were disposed of, the mutual translation of the scales would be simple, since the two units are to each other inversely as the number of them in any given range.

To reduce F. above melting ice to terms of C., 32° must first be subtracted from the given F. temperature, then multiply the remainder by $\frac{5}{9}$; the product will be the C. term for the given temperature; and conversely divide C. by $\frac{5}{9}$ and add 32 to translate C. into F.; to prove the work, read the terms across the diagram in the table. Below melting ice, the same rules as given above apply, except that where 32 is added above, it should be subtracted here, and *vice versa*.

In the columns at the right hand of each diagram in this table, are found the approximate steam pressures per square inch, due to the adjoining indications of temperature. The pressure is expressed in pounds and in atmospheres.

The high pressures are obtained from the several authors who have deduced and tabulated them from experiments and formulas of Regnault and others; and being hypothetical, accuracy is not claimed for them.

COMPARISON OF CENTIGRADE AND FAHRENHEIT SCALES, AND APPROXIMATE STEAM PRESSURE IN POUNDS AND ATMOSPHERES PER SQUARE INCH DUE TO THE TEMPERATURE.

Thermometer.		Steam. Non-condensing Engine.		
Centi.	Fahr.	Pres. per gauge. lbs.	Total Press. Lbs.	Total Press. Atmos.
260	500	665	680	46.
255	491	610	625	42.
250	482	560	575	39.
245	473	515	530	36.
240	464	472	487	33.
235	455	430	445	30.
230	446	390	405	27.5
225	437	354	369	25.
220	428	321	336	23.
215	419	290	305	20.7
210	410	262	277	18.8
205	401	235	250	17.
200	392	211	226	15.3
195	383	188	203	13.8
190	374	167	182	12.4
185	365	148	163	11.1
180	356	131	146	9.9
175	347	115	130	8.8
170	338	100	115	7.8
165	329	85	100	6.8
160	320	73	88	6.
155	311	63	78	5.3
150	302	55	70	4.7
145	293	45	60	4.1
140	284	37	52	3.5
135	275	30	45	3.
130	266	25	40	2.7
125	257	19	34	2.3
120	248	14	29	1.9
115	239	10	25	1.6
110	230	6	21	1.4
105	221	3	18	1.2

Thermometer.		
Centi.	Fahr.	
100	212	
95	203	
90	194	
85	185	
80	176	
75	167	Temp. of Condenser.
70	158	
65	149	
60	140	
55	131	
50	122	
45	113	
40	104	
35	95	
30	86	
25	77	
20	68	
15	59	
10	50	
5	41	
0	32	
— 5	23	
—10	14	
—15	5	
—20	0 — 4	
—25	—13	
—30	—22	
—35	—31	
—40	—40	
—45	—49	

Steam. Condensing Engine.			
Press. per gauge.		Back Press. Lbs.	Back Press. Atmos.
0		14.7	1.
Vacuum, effective.		Lbs.	Atmos.
Gauge.	Lbs.*	12.	0.85
9½	4.7	10.	0.7
12½	6.2	8.5	0.6
15½	7.7	7.	0.5
18¼	9.1	5.6	0.4
20½	10.2	4.5	0.3
22	11.	3.7	
24	11.9	2.8	0.2
25	12.4	2.3	
26	12.9	1.8	0.2
26½	13.3	1.4	
27¾	13.6	1.1	0.1
28½	13.8	.9	
29	13.9	.8	

* To be added to the pressure indicated by steam gauge to get total pressure on piston.

M. T. Mines of Brittany, 500 ft., . . . 59 F.
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Max. density of water, 39.2 F. / 4 C.
Melting Ice, . 32 F. —0 C.
Blood freezes, . . 25 F.
Castor Oil freezes, . 21 F.
Spirits of turpentine freezes, . . 14 F.
Brandy freezes, . —7 F.
Mercury freezes, . —40 F.
Sulphuric Acid (1.841) freezes, . . —45 F.
Greatest artificial cold, . —166 to —220 F.
Absolute cold, . —459.4 F. / —273. C.

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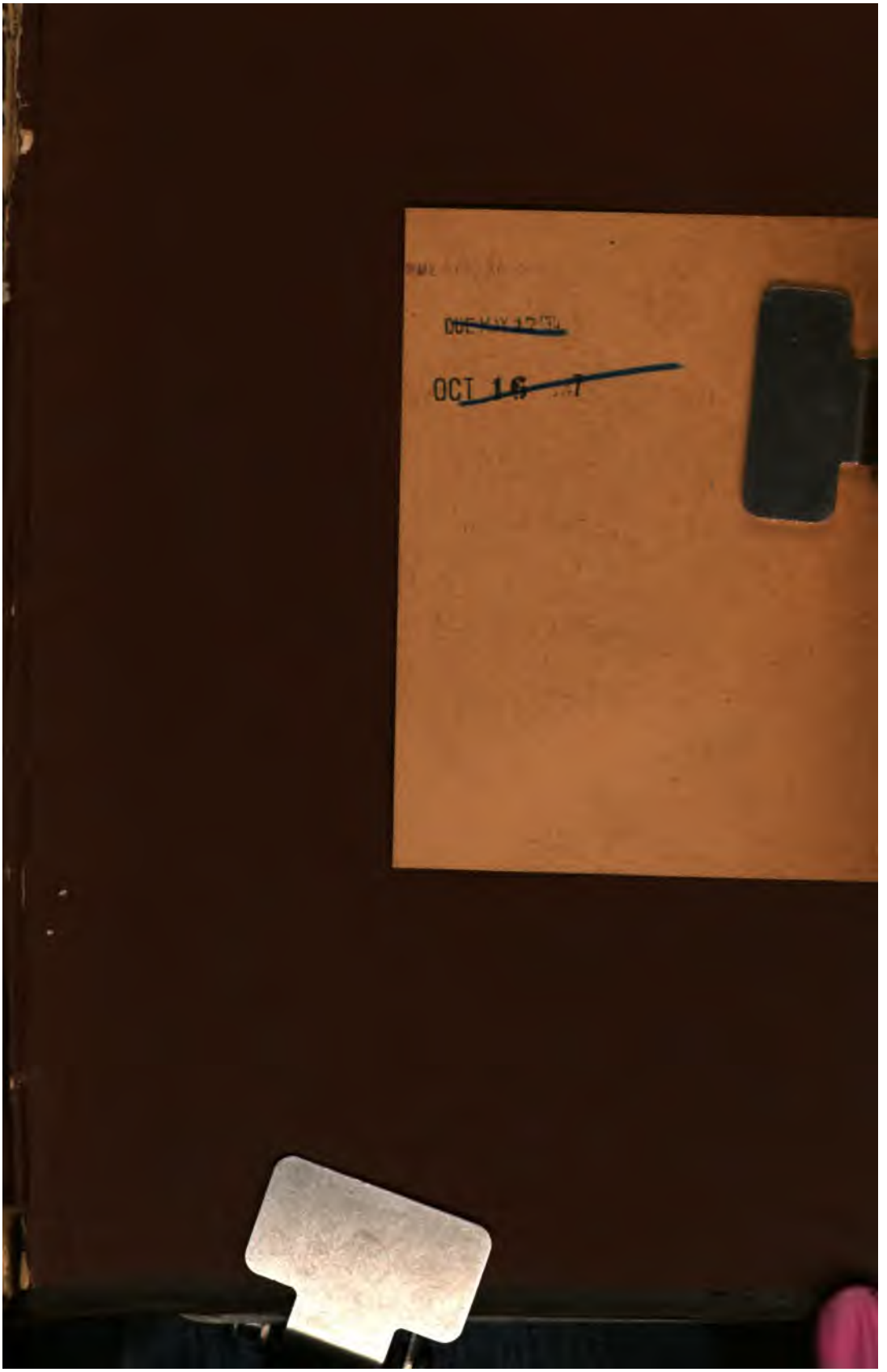
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